VOL. XII APRIL 1958 NO. 2

PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

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Distribution and Ecologic Aspects of Central Pacific Salpidae (Tunicata)[1]

JAMES L. YOUNT[2]

THE PRESENT REPORT is a continuation of a general salp study, the first section of which already has been reported (Yount, 1954). It concerns the distribution and ecology of the salps collected during two cruises by the "Hugh M. Smith" of the Pacific Oceanic Fishery Investigations of the United States Fish and Wildlife Service (referred to in the remainder of this report as POFI) in the central Pacific Ocean. Nineteen out of a total of 22 recognized world species were found in these collections.

Knowledge of the distribution of salps was reviewed by Traustedt (1885), Apstein (1894, 1906), Metcalf (1918), Ihle (1935), and Thompson (1948). Various other investigators have added to this general knowledge in regard to certain species. Certain points in regard to geographic distribution, however, needed clarification. Among these was an investigation of the usefulness of salps as indicator species of oceanic currents within the area of study. Moreover, knowledge of seasonal effects on salps, of the relation of salp abundance to the abundance of other zooplankton, and of the relation of salp abundance to physicochemical environmental factors was very limited. Thus studies were carried out, insofar as the available data would permit, in an attempt to elucidate these points. In addition, little information exists defining the actual role or position of salps in the plankton community (the niche as defined by Elton, 1927); consequently, the niche of the different salp species was investigated as thoroughly as possible.

ACKNOWLEDGEMENTS

I wish to express my gratitude to R. W. Hiatt and L. D. Tuthill for their help throughout this investigation. O. E. Sette of POFI, in addition to permitting me to use the plankton collections, reviewed the manuscript in part. I also wish to thank T. S. Austin of POFI for his help with regard to the section *Physicochemical Factors of the Environment*. J. E. King of POFI helped by furnishing information on total plankton volumes and numbers of the collections examined.

MATERIALS AND METHODS

The animals used were taken from a large series of plankton captures made by POFI in an area that extended from 27° N. to 15° S. and from 176° W. to 155° W. In this area, the "Hugh M. Smith" made cruise 5 in June, July, and August of 1950, and cruise 8 in January, February, and March of 1951, thus permitting seasonal comparisons. The study of abundance and distribution was confined to cruises 5 and 8; of these cruises, all samples (51) from cruise 5, and 30 samples out of 106 from cruise 8, were studied.

[1] Contribution No. 99, Hawaii Marine Laboratory, in cooperation with the Department of Zoology and Entomology, University of Hawaii. Part of a thesis submitted to the Department of Zoology, University of Hawaii, in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] Department of Biology, University of Florida, Gainesville, Florida. Manuscript received August 27, 1956.

The total plankton data used here were reported by King and Demond (1953); Cromwell (1953, 1954) reported all hydrographic observations used here. As King and Demond stated, the plankton net descended obliquely to 200 meters, then made an oblique ascent to the surface. Thus the net strained, during approximately 30 minutes, a total of about 1,000 cubic meters of water. This net was described in King and Demond's report as being 1 meter in diameter, with a mesh width of 0.65 mm., but I should point out here that it was an open net. For this reason, vertical distribution of the captured animals is unknown.

All animals larger than about 5 cm. were removed from each POFI plankton sample (King and Demond, 1953). The sample was then divided into two equal portions, one of which was not used by POFI personnel. The latter portions were used for the present study. Therefore, in calculations where comparisons were necessary, salp numbers and volumes were estimated by doubling the figure obtained from each half sample. In addition, many of the removed salps larger than 5 cm. were examined and identified. Number determinations of salps were made by direct counting, whereas volume determinations of the salps were made for each plankton sample by means of water displacement in a graduated cylinder. In order to determine the relation between salp volume and volume of the other plankton in the same sample, the salp volume determinations were divided by the amount of water strained (taken from King and Demond) and compared with the total volumes of zooplankton, less salps, reported by King and Demond.

ABUNDANCE OF SALPS

Physicochemical Factors of the Environment

A study of the ecology of salps should consider all aspects of their environment such as food, enemies, and the distribution of physicochemical factors of the waters in which they are found. Of possible direct importance to them is the distribution of temperature, density, currents, salinity, and oxygen. On the other hand, distribution of light and of nutrient chemicals, factors which influence phytoplankton production, is probably only indirectly important to salps. Which among these are limiting factors for salps is almost wholly unknown.

In the open ocean, salinity is presumed not limiting because of its small variation, from about 34 to 36 ‰. Salps seem to be absent from areas of very low or high salinity, such as may be found in certain waters. For example, Apstein (1906) reported no salps from the region off the mouth of the Congo River in Africa, a situation apparently related to the low salinity (30.4 ‰) in the area; and Ihle (1935) noted that some species of salps were absent from the eastern part of the Mediterranean Sea, perhaps indicating a relationship to the high salinity (up to 40 ‰ off Syria).

In regard to temperature, also, little is known about limits of tolerance for the various species, although all salp species—except an antarctic form, *Ihlea magalhanica*—are found principally in warm regions of the ocean. Occasionally they are found in high latitudes, presumably carried there by current tongues, for example, in the Bering Sea (Metcalf, 1918), the Gulf of Maine (Bigelow, 1926), the North Sea (Fraser, 1949, 1954), and waters of southern Australia (Thompson, 1948). Salps have also been found at great depths (more than 1,000 meters) where the temperature was low (Apstein, 1906; Michael, 1918; Sewell, 1926, 1953; Leavitt, 1935, 1938). The limits of tolerance for both salinity and temperature in the various species are thus unknown and can only be inferred from reports of distribution.

Factors that influence variation in organic productivity must also be considered for a clear understanding of variation in salp abundance. Areas of maximum biological productivity are found in coastal waters, in temperate and higher latitudes, and in regions of upwelling. Productivity in these areas is based

chiefly on vertical mixing of the waters (Sverdrup, *et al.*, 1942: 785; Tait, 1952: 76; Harvey, 1955: 99) and additions of dissolved nutrients from the land (Künne, 1950: 57; Dakin, 1952: 7), which bring nutrients to the euphotic zone where they can be used. In temperate waters, vertical mixing and resultant enrichment are useful for production principally in the spring and fall; in midwinter the standing crop of organisms is low, due primarily to insufficient light intensity, while in midsummer the low standing crop is apparently the result of depletion of nutrients in the euphotic zone (Russell and Yonge, 1936: 246). In tropical waters, on the other hand, there is generally a low concentration of nutrients in the euphotic zone with an attendant low standing crop throughout the year, apparently because upper tropical waters (to a depth of about 300 meters) are characterized by a three-layer system—an upper warm layer, a transition layer, and a lower cool one—present during a large portion of the year. Thus sinking of decomposing substances from the surface layer to a depth below the transition layer results in a removal of nutrients from the euphotic zone until vertical mixing of the waters again brings the nutrients back.

The enrichment in the zone between about 2° N. and 5° S. in the area studied undoubtedly originates principally from vertical water movements; i.e., it probably does not originate in the Peru Current from the east. The phosphate and standing crops of the region studied probably also reflect, in small part, a horizontal movement of water from the east. No quantitative data on the westerly limits of the effects of the Peru Current are available, but considering the great distance involved, one can assume that the phosphate from upwelling in the Peru Current is utilized long before reaching the meridians studied. In other words, the water from the Peru Current has "aged" by the time it reaches these meridians, i.e., has moved far from the upwelling which initially enriched it (Steemann-Nielsen, 1954). However, since these waters of the meridians studied are in a continuous state of upwelling they are "young," that is, they have a high concentration of nutrient chemicals, being more or less continuously replenished from below.

Another factor should be considered in regard to enrichment: phosphates probably affect salps only indirectly. As only plants are considered able to utilize dissolved nutrients such as phosphates for biological production, salps are probably affected by phosphates only by way of their food, which consists primarily of phytoplankters. Salps thus stand one trophic level away from the dissolved nutrients as shown by their trophic relationships: dissolved nutrients → phytoplankton (producers) → herbivorous zooplankton (primary consumers). Time, therefore, is required for the phosphates to be used by the phytoplankton in order that the primary consumers can be affected by the increased production. For this reason, it is possible that the salps captured at the same time would show little correlation, station to station, with the phosphates. However, the increased phosphate found in the region of upwelling is a zonal condition and thus not transient, and results in generally larger standing crops of plankton in this region (Cromwell, 1953; King and Demond, 1953).

Considering the above factors, then, one would expect increased availability of nutrients in the regions of upwelling and in other regions in which frequent vertical mixing occurs, such as in zones of shear at the edge of currents (the regions of "Ansammlungen" of Apstein, 1906), and in waters near island masses where vertical mixing and diffusion may occur as a result of eddies and where dissolved nutrients from the land may be added. Therefore, the a priori expectation for this study was that larger standing crops of salps would be related to those ecologic factors favorable to biological production.

One further subject—that of the sources of error to which the results are liable—should be discussed before a description of the meri-

dional sections is given. King and Demond (1953) described the possible errors in regard to the total zooplankton, and a large part of the following review is based on their report.

One source of error is from the fact that estimates of each plankton sample were made by doubling the figures obtained by direct measurement and counting of the half samples. In addition to the halving of each plankton sample, another source of error comes from the removal of organisms larger than 5 cm. from each of the samples. Undoubtedly this removal of large salps has considerably reduced the volume of capture at some stations.

Day-night variation was shown by King and Demond to have had considerable influence on the total zooplankton of cruises 5 and 8, but there was no important effect of this variate on salps, at least in the 0–200 meter layer. This is in agreement with the report of Apstein (1906), who considered that, in general, salps perform no diurnal vertical migrations. One species, *Thalia democratica*, however, was considered by Michael (1918) to migrate vertically as a result of temperature variations and reproductive behavior. Hardy (1936) and Fraser (1949) have given evidence that indicates a nightly movement toward the surface, but their tows were shallower than 200 meters.

Perhaps the most important source of error is the "patchy" distribution, both horizontally and vertically, of plankters in general. Nothing is known of the extent to which the variations in capture of the plankters is reliable: i.e., there is doubt as to whether there is a true ecologic difference between the capture at one station of 1 cc. of salps/1000m^3 and the capture at another station of 1.5 or 2 cc/1000m^3. Perhaps the difference is due simply to variation that could be expected from the method of capture alone or from the patchiness of the salps. A better way to minimize this error would be to take a series of plankton tows at each station so that an average could be obtained. This was impractical for the POFI cruises. In order to minimize patchiness, on cruises 5 and 8 only oblique tows were made, as the oblique tow has been regarded by Winsor and Clarke (1940) as well as by King and Demond (1953) as more efficient than either horizontal or vertical tows. By this oblique towing method, a large volume of water was strained; King and De[illegible]d assumed, therefore, that "variation in catch due to the uneven distribution of organisms is minimized" (p. 119). However, in view of the small volumes and numbers of salps observed occasionally, the actual population density may have been quite different.

The POFI cruises traversed three principal currents in the central Pacific: the westerly flowing North Equatorial Current which arises in part from waters of the California Current; the easterly Counter Current, with its source waters primarily from the neighborhood of the southern Philippine Islands and New Guinea; and the westerly South Equatorial Current fed from the Peru Current and the Gulf of Panama. Figures 1 and 2 show this region and the stations where the plankton samples were collected. For purposes of this report, the data from cruise 5, 172° W. are used as an example of the currents disclosed by a meridional section (cf. Fig. 4). The North Equatorial Current flows mainly westerly from the Hawaiian Islands (27° N., station 1) to the northern limit of the Counter Current at about 8° N., station 14; the easterly flowing Equatorial Counter Current (from about 8° N., station 14, to 4° N., station 18); and the westerly flowing South Equatorial Current (from about 4° N., station 18) to the southern limit of the section.

Since the surface phosphate concentration is associated with the stratification of the water, which is in turn primarily dependent on the temperature, the vertical sections for these two parameters are closely related. Because the vertical temperature sections are so revealing, they are used to describe the general ecologic features to be considered with

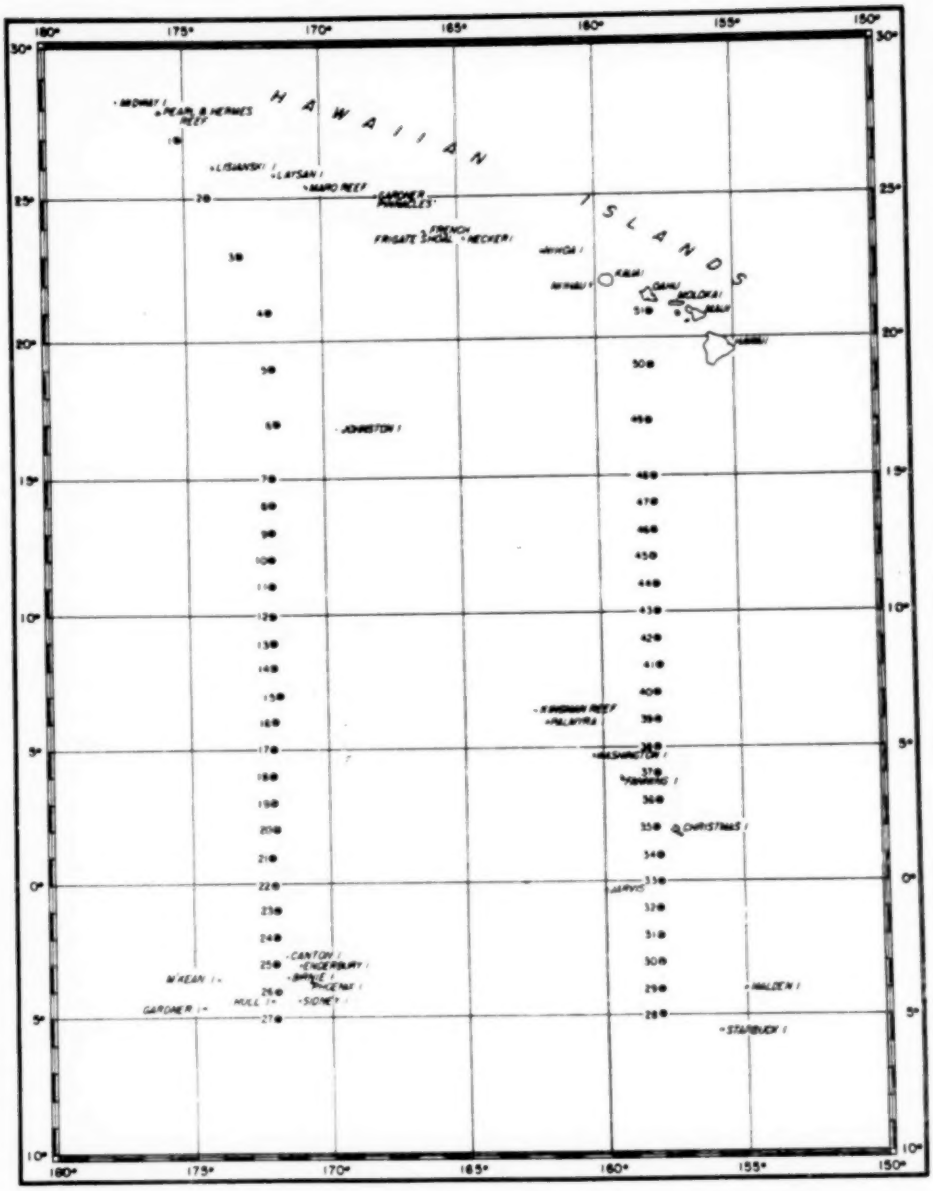
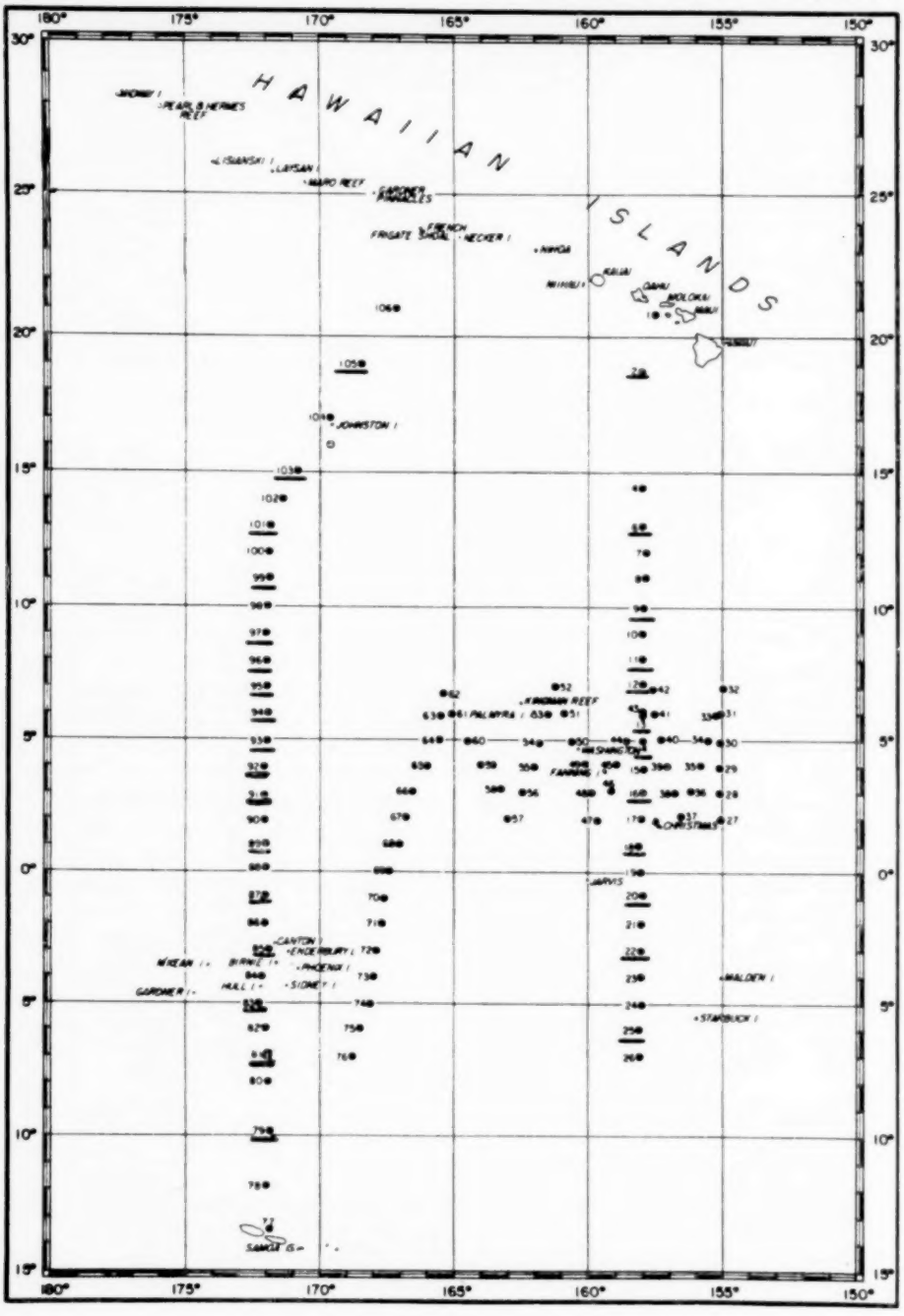


FIG. 1. "Hugh M. Smith," cruise 5; June–August, 1950. Numbers 1–51 indicate stations at which plankton tows and hydrographic observations were made. (After Cromwell, 1954.)


180°
175°
170°
165°
160°
155°
150°
30°
25°
20°
15°
10°
5°
0°
5°
10°
15°
HAWAIIAN ISLANDS
JOHNST I
PEARL & HERMES REEF
LISIANSKI I
LAYSAN I
MARO REEF
GARDNER PINNACLES
FRIGATE SHOAL
FRENCH
NECKER I
NIHOA
KAUAI
NIIHAU I
OAHU
MOLOKAI
MAUI
KURE I
JOHNSTON I
KINGMAN REEF
PALMYRA I
WASHINGTON I
FANNING I
CHRISTMAS I
JARVIS
CANTON I
ENDERBURY I
MCKEAN I
PHOENIX I
GARDNER I
HULL I
SIDNEY I
MALDEN I
STARBUCK I
SAMOA IS.

each of the meridional series of salp samples. It should be pointed out, however, that the distribution of the other determined factors—density, salinity, inorganic phosphates, and dissolved oxygen—is very similar on all meridians studied here (see Cromwell, 1954). The detailed descriptions of all parameters studied may be found in Cromwell (1953, 1954).

Considering the emphasis to be placed on temperature, it is desirable to describe its major variations. It was found (Cromwell, 1954) that temperature distribution in the North Equatorial Current was characterized by a relatively poorly developed thermocline. The region of the Counter Current (about 8° N. to 4° N.) was characterized by a gradual north-south sharpening of the thermocline and a deepening of this layer to the south. The northern part of the South Equatorial Current was characterized by a well-developed, deep thermocline in the region of upwelling. South of this region, the thermocline again became less well defined. Inspection of the temperature distribution (Cromwell, 1954, fig. 6) shows conical isotherms resulting from an upward transport of the cooler waters of the lower surface layer and upper thermocline from 1° N. to 2° S. This is associated with the wind-induced divergence and the attendant upwelling, as evidenced by the cooler temperature found at the surface.

As the histograms in Figures 3 to 6 show, the salps discussed herein were taken on two meridional sections during cruises 5 and 8 of the "Hugh M. Smith." The histograms show the observed variation of the total salp volume, total salp numbers, and the numbers of the commonest species, *Thalia democratica*, *Salpa fusiformis*, *Ritteriella amboinensis*, and *Cyclosalpa pinnata*. A typical section, cruise 5, 158° W., is discussed in detail and the remaining sections are compared with it.

The typical section (Fig. 3) shows that the majority of the relatively large volumes were taken from 1° S. to 4° N., in or near the region of upwelling which was characterized by low temperature and a high phosphate value. Large volumes were also taken from 17° to 21° N., apparently due to the influence of the Hawaiian Islands.

Total numbers of salps (Fig. 3*a*) showed a very different distribution from that of total volume, as can be expected, since a few large specimens may greatly influence volume but not numbers. Inasmuch as *Thalia democratica* comprised the principal portion of the total numbers at most stations, it is discussed simultaneously with total numbers. The greatest numbers were taken in the region under influence of the upwelled waters but large numbers were also taken in waters far from this region (15°N.), a fact which may be explained by the presence of a current shear and/or eddies associated with the Hawaiian Islands. The large numbers taken at 4°, 5°, and 9° N. appear to be associated with the shearing effect at the southern and northern boundaries of the Counter Current. The majority of the small numbers occurred away from the upwelled region, in regions where the previously described layered system was well developed and the phosphates in the euphotic zone were low.

The other common species show a rather different distribution (Fig. 3*b*). *Salpa fusiformis* was most abundant near the region of upwelling. No substantial influence was shown by proximity to islands. *Ritteriella amboinensis* was taken in greatest numbers near the upwelling and in regions possibly influenced by proximity to islands. *Cyclosalpa pinnata* occurred only in small numbers; nevertheless, its principal occurrence was in the region of upwelling in the South Equatorial Current. It does not appear to have been influenced by other factors examined.

The section of cruise 5, 172° W. (Fig. 4), is characterized by a more general meridional

FIG. 2. "Hugh M. Smith," cruise 8, January–March, 1951. Numbers 1–106 indicate stations at which plankton tows and hydrographic observations were made. The underlined numbers represent stations examined for the present study. (After Cromwell, 1954.)

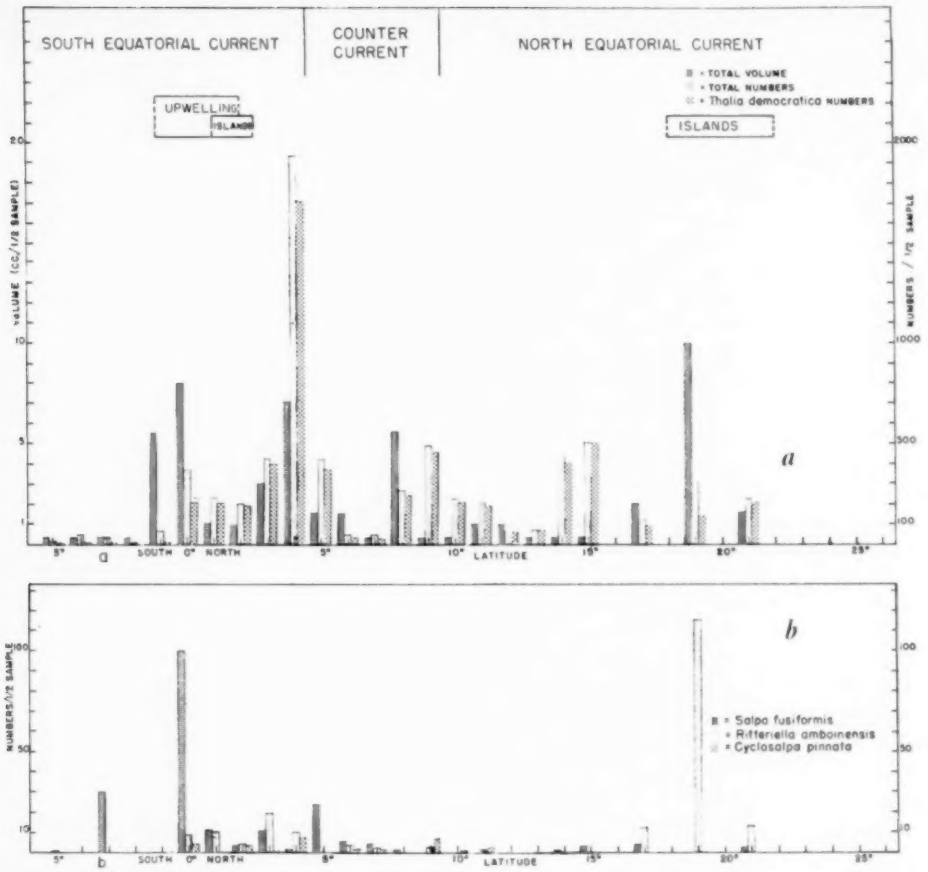


FIG. 3. Cruise 5, 158° longitude. *a*, Relationship of total salp volume, total salp numbers, and numbers of *Thalia democratica* to major currents, upwelling, and island masses. Limits of currents, upwelling, and islands are approximate. *b*, Relationship of the other common species, *Salpa fusiformis*, *Ritteriella amboinensis*, and *Cyclosalpa pinnata* to major factors listed in *a*.

distribution with indications of increased volumes near the equator, near the current shear at the margin of the Counter and North Equatorial Currents, and in waters near the Hawaiian Islands. Relatively great total numbers and numbers of *Thalia democratica* were taken near the region of upwelling and in waters near the Hawaiian Islands. The abundance of the other species shows little apparent relation to the ecologic factors being considered, but there was a tendency to greater numbers in the region of upwelling.

In regard to the section of cruise 8, 158° W. (Fig. 5), the distribution of the volumes appears to be random, showing little apparent relation to the ecologic factors examined except in one instance (10° N.), where a relatively large volume was taken in the region of current shear between the margins of the Counter and North Equatorial Currents. The distribution of total numbers and of numbers of the common species also showed little

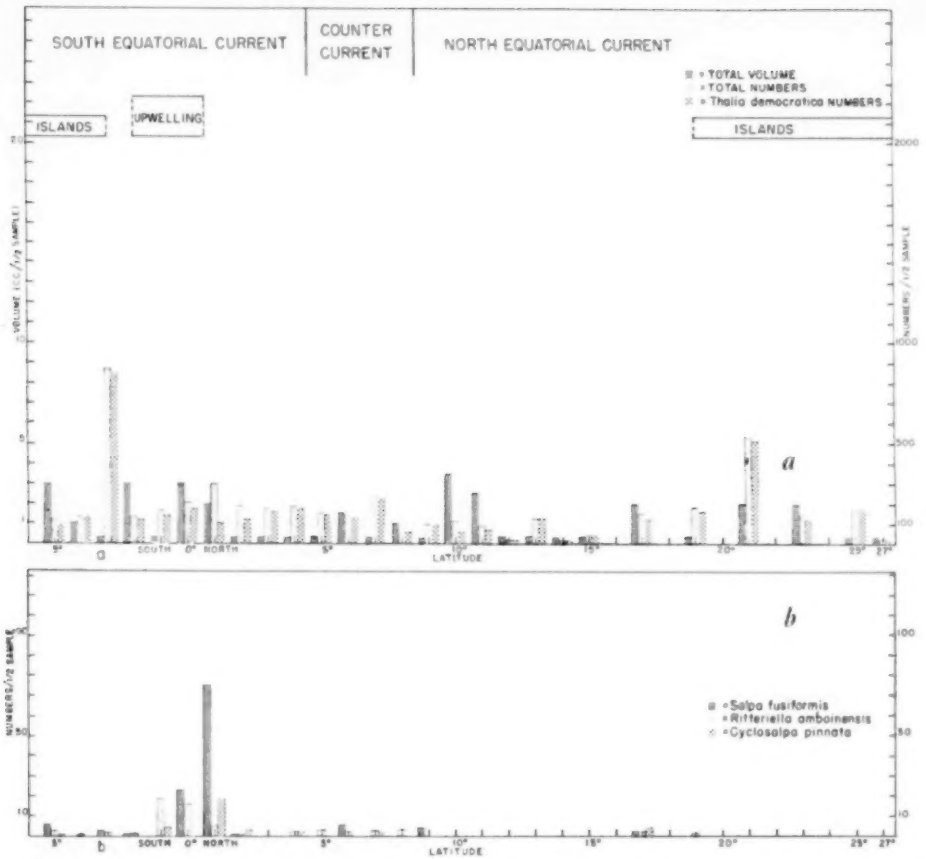


FIG. 4. Cruise 5, 172° W. longitude. *a*, Relationship of total salp volume, total salp numbers, and numbers of *Thalia democratica* to major currents, upwelling, and island masses. Limits of currents, upwelling, and islands are approximate. *b*, Relationship of the other common species, *Salpa fusiformis*, *Ritteriella amboinensis*, and *Cyclosalpa pinnata* to major factors listed in *a*.

relationship to the ecologic factors examined.

The section of cruise 8, 172° W. (Fig. 6), shows that relatively large volumes were taken in the region of upwelling and near the current margins of the Counter and North Equatorial Currents. Relatively great numbers were taken also in these regions, with a predominance of the greater numbers near the region of upwelling.

In summary, it can be stated that most of the greater volumes and numbers of salps taken on these longitudes were taken either within or near the cool enriched upwelled waters, in regions possibly influenced by current shear, or in regions in which there was a possible island influence on their abundance. The effect of temperature on salp abundance is undoubtedly only indirect within the ranges found on these cruises, inasmuch as cool non-upwelled waters contained, in general, relatively few salps except near islands. This predominance of greater volumes in regions of upwelling occurred on cruise 5, 158° and 172° W., and cruise 8, 172° W. The abundance

of the salps on cruise 8, 158° W., appeared to be unrelated to upwelling, however. There appears to have been an influence of island proximity on salp abundance on cruise 5, 158° and 172° W. It apparently had no effect on the abundance at either longitude of cruise 8. The influence of shearing at current margins apparently affected salp abundance on cruise 5, 158° W., and cruise 8, 158° W. Other than these, no relationships of salps to ecologic factors can be determined from the available data.

Relative Abundance of Species

The most numerous species of salp in the POFI collections is *Thalia democratica*. In the central Pacific Ocean, therefore, the statement of Apstein (1906) that this species is the commonest salp in warm water holds true. Similarly, in the East Indies (Ihle, 1910), the Philippines (Metcalf, 1918), the Great Barrier Reef lagoon (Russell and Colman, 1935), and southeast Australia (Thompson, 1948), *T. democratica* is the commonest species found. However, it was reported by Ritter (1905) as

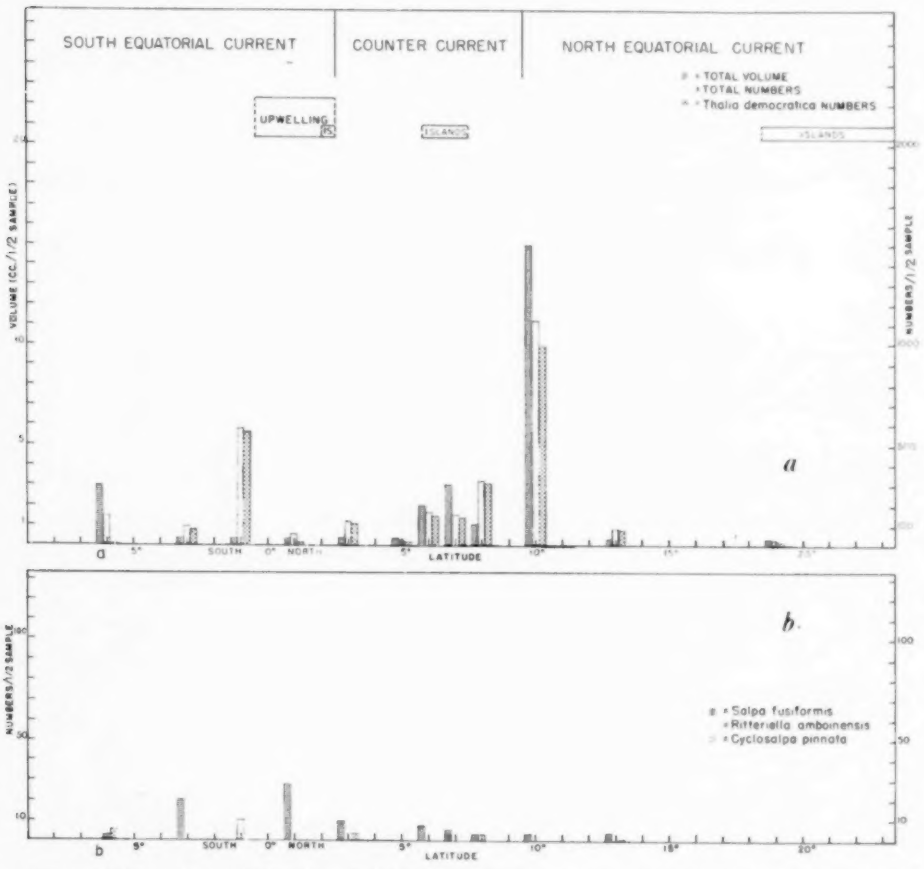


FIG. 5. Cruise 8, 158° W. longitude. *a*, Relationship of total salp volume, total salp numbers, and numbers of *Thalia democratica* to major currents, upwelling, and island masses. Limits of currents, upwelling, and islands are approximate. *b*, Relationship of the other common species, *Salpa fusiformis*, *Ritteriella amboinensis*, and *Cyclosalpa pinnata* to major factors listed in *a*.

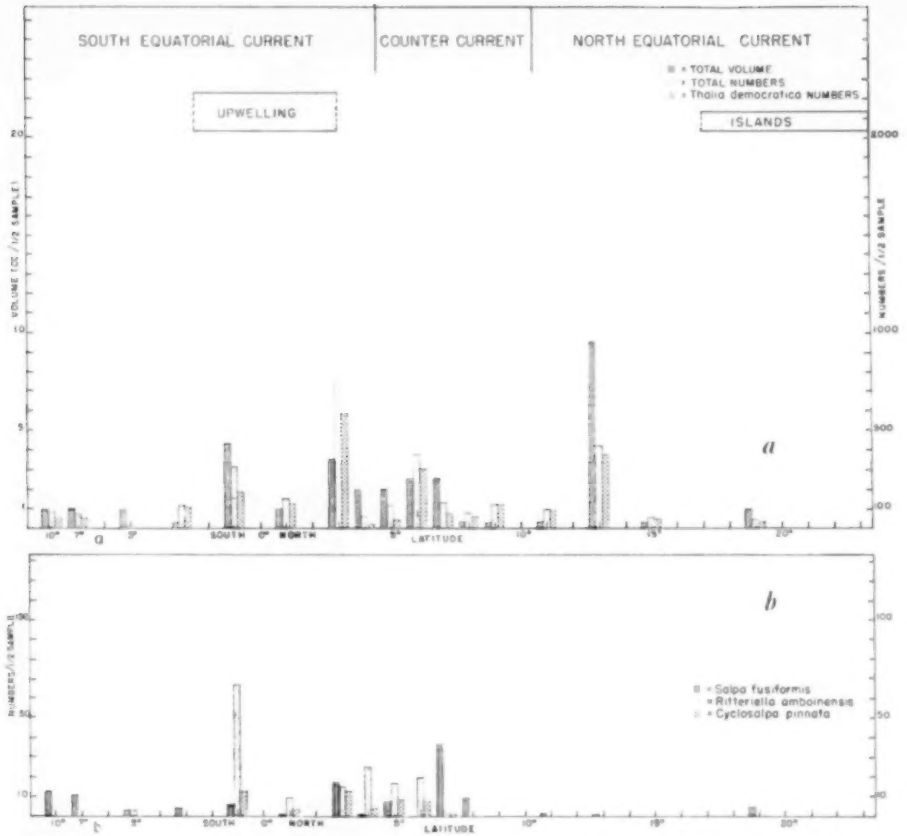


FIG. 6. Cruise 8, 172° W. longitude. *a*, Relationship of total salp volume, total salp numbers, and numbers of *Thalia democratica* to major currents, upwelling, and island masses. Limits of currents, upwelling, and islands are approximate. *b*, Relationship of the other common species, *Salpa fusiformis*, *Ritteriella amboinensis*, and *Cyclosalpa pinnata* to major factors listed in *a*.

being less abundant than *Salpa fusiformis* off the coast of California; this is perhaps a result of the lower temperatures in California waters.

RELATIVE IMPORTANCE OF DOMINANT SALP SPECIES IN THE CENTRAL PACIFIC

Frequency of occurrence by station

Cruise 5	Cruise 8
1. *Thalia democratica*	*Thalia democratica*
2. *Ritteriella amboinensis*	*Salpa fusiformis*
3. *Salpa fusiformis*	*Ritteriella amboinensis* and *Cyclosalpa pinnata*

Numerical ranking of species

1. *Thalia democratica*	*Thalia democratica*
2. *Salpa fusiformis*	*Traustedtia multitentaculata*
3. *Ritteriella amboinensis*	*Salpa fusiformis*

Frequency of dominance by volume

1. *Iasis zonaria* and *Ritteriella amboinensis*	*Ritteriella amboinensis* and *Thalia democratica*
2. *Thalia democratica*	*Salpa fusiformis*

The chief salp component by volume in the central Pacific varies irregularly at the different stations. As volume is difficult to determine precisely, especially when there are few specimens of small species, volumes were determined to the nearest cubic centimeter and the chief component species was estimated by visual inspection. In some samples no one species predominated but usually one species predominated volumetrically; the same species or a different one might predominate numerically. The chief component species by volume may be a single specimen of a large species or a few specimens of a medium sized species, which may predominate over even large numbers of smaller species such as *T. democratica*. Inasmuch as specimens larger than 5 cm. were removed from the samples before the present study, the volumetric data may be incorrect for some stations, although, as King and Demond stated, these larger specimens were infrequent.

Comparison of Salp Abundance with Total Plankton Abundance

King and Demond (1953) have reported on the total plankton of cruises 5 and 8 by volume and numbers per cubic meter of water strained. The original numerical estimates and volume determinations were made available through the courtesy of Mr. King and the salp percentages discussed here were calculated from them.

Salps comprised more than 50 per cent of total plankton by volume at only one station (50) of cruise 5 (54 per cent); the highest percentage by number made up by salps was 9.1 per cent, at station 48 of cruise 5. On cruise 8, salps amounted to more than 50 per cent of the total volume at stations 9 (58 per cent) and 101 (65 per cent); the highest percentage by number was 4.1, at station 9.

These results, combined with the numerical percentage estimates of tunicates as compared with other zooplankters by King and Demond, show that tunicates in general play a relatively small numerical role in the central Pacific plankton, but that salps in particular may attain a substantial volume as compared with other plankters. Ordinarily, however, salps play a rather minor role both volumetrically and numerically. Thompson (1942) stated, in reference to southeastern Australian waters, "Tunicates . . . comprise, next to Crustacea, the chief portion of the zooplankton," and, "Tunicates (chiefly salps) are the only other group which frequently predominates . . .," with a monthly average percentage of 25.4 as compared to 62.5 per cent for Crustacea. Thus, although the methods of capture are not strictly comparable, there is evidently a rather pronounced difference in the composition of the plankton between the central Pacific and southeastern Australian waters.

By using the methods described in Snedecor (1946, chap. 7), correlation coefficients were calculated to determine the relationship between salp numbers and zooplankton numbers (less salps) and salp volume and zooplankton volume (less salps) for cruises 5 and 8. In order to make use of salp volumes that measured less than 1 cc., such volumes were given an assumed measure of 0.5 cc. in the calculations. Neither correlation coefficient was significant for numbers or volumes of these cruises. From the evidence based on these cruises, then, there is no significant mutual relationship between salp and zooplankton numbers or volumes.

Comparison of Salp Abundance in the Central Pacific with Other Regions of the Pacific

It is impossible to make accurate quantitative comparisons between the plankton of different regions unless equipment and methods of capture are standardized. Unfortunately such optimal conditions have never been met. Nevertheless, as salps are relatively large animals and thus are taken by the commonly used nets, an attempt is made here to compare the salps of the central Pacific to those of the Great Barrier Reef lagoon as reported upon by Russell and Colman (1931, 1935), the only Pacific investigators who have

listed salps and other zooplankters by station and numerical frequency. Such a comparison is made more reliable by the fact that Russell and Colman used a 1-meter coarse international silk townet, which has an approximate mesh width of 0.42 mm.; the 1-meter nets used by POFI have a mesh width of 0.65 mm. (King and Demond, 1953). In addition, Russell and Colman towed their nets obliquely at each station for approximately a half hour, as was done for the POFI collections.

The chief difficulties with such a comparison are: (1) the amount of water strained was not computed by Russell and Colman and thus estimates of relative abundance of the plankton are only approximate; (2) volumes of the different groups of plankters were not determined for the Great Barrier Reef collections and thus, number of organisms, a relatively poor measure, offers the only means of comparison; and (3) the depth to which the POFI tows were made was approximately 200 meters, whereas those of the Great Barrier Reef Expedition were made to approximately 30 meters.

Russell and Colman (1935) listed the tunicates which occurred in oblique tows with the 1-meter coarse silk townet by species, reproductive form, and numerical frequency at 59 stations of the Great Barrier Reef lagoon. Comparison of these data with the data from the central Pacific reveals some striking differences. Only 6 salp species (4 with the coarse silk townet) were captured in the Barrier Reef lagoon, whereas 19 (16 on cruises 5 and 8) were captured in the central Pacific. *Thalia democratica* was by far the most numerous and frequently occurring species (80,987 specimens at 39 Barrier Reef stations), as it also was in the central Pacific. The fact, however, that *T. democratica* was lacking from fully 20 of the 59 Barrier Reef stations is surprising when compared with the POFI collections, where it was absent at only 2 out of 81 stations examined. In addition, this species was occasionally much more numerous in the Barrier Reef lagoon than in the central Pacific (maximum numbers at one station of 17,000 and 3,440, respectively).

The other species found in the Great Barrier Reef lagoon rank among the relatively less common and infrequently occurring species in the central Pacific: *Brooksia rostrata* occurred in the Barrier Reef at 10 stations out of 59 (117 specimens), whereas in the POFI collections, it occurred at 24 stations out of 81 (259 specimens); 111 specimens of *Pegea confoederata* occurred at 8 stations out of 59 in the Barrier Reef, whereas 185 specimens occurred at 12 stations out of 81 in the central Pacific; *Weelia cylindrica* occurred at 13 stations (53 specimens) out of 59 from the Great Barrier Reef, whereas it occurred at 23 stations out of the 81 POFI collections examined (259 specimens). With the exception of *T. democratica*, the most numerous and frequently occurring species in the POFI collections, *Salpa fusiformis*, *Ritteriella amboinensis*, *Cyclosalpa pinnata*, and *Traustedtia multitentaculata*, did not occur at all in the Great Barrier Reef collections. All of these species, however, occur in oceanic Australian waters (Thompson, 1948).

Another striking difference between the collections from the Great Barrier Reef and those from the central Pacific is the large number of stations from the former at which no salps occurred (15 out of the 59 listed), whereas in the POFI collections, salps occurred at all 81 stations examined. In addition to the 59 tunicate-containing stations listed by Russell and Colman, there were 9 other collections made, which contained no tunicates.

On examining their data, another difference becomes evident; that is, a maximum of 17,003 specimens of salps (almost all *T. democratica*) was captured at one station, whereas the maximum number at any one station in the POFI collections was 3,864 (chiefly *T. democratica*). The maximum number of salp species taken with the coarse silk townet at any one station in the Great Barrier Reef,

however, was only 4; in the POFI collections, the maximum number of species at any one station was 9, more than twice the maximum number from the Barrier Reef.

In summary, then, bearing in mind the difficulties of quantitative comparisons, the chief differences between the Salpidae of the Great Barrier Reef lagoon and of the central Pacific Ocean, based on limited captures, are as follows: (1) the numbers of species found are much fewer as a whole in the Great Barrier Reef than in the central Pacific; (2) the maximum numbers of species present at any one station are much fewer in the Barrier Reef than in the central Pacific; (3) the numbers of individuals at any one station are often much greater in the Barrier Reef than in the central Pacific; (4) salps are more highly sporadic in distribution in the Barrier Reef than in the central Pacific, even being entirely absent from many stations, whereas they are present in all the POFI collections; (5) the most numerous and frequently occurring species, *T. democratica*, is the same in the two areas, but the species ranking next numerically and in frequency of occurrence are entirely different. Species other than *T. democratica* found in the Barrier Reef lagoon are relatively sparse and infrequent in the central Pacific collections, while the ranking species, other than *T. democratica*, of the central Pacific are wholly lacking from the Barrier Reef collections, although they occur offshore in the Australian region. These differences probably reflect chiefly the widely differing ecologic conditions between a neritic and an oceanic environment.

DISTRIBUTION OF SALPS

Geographic Distribution

Almost all investigators of planktonic animals have concurred with Giesbrecht's observation that, ". . . the epipelagic high-oceanic fauna may be divided into three main zoogeographical regions: a warm-water and a northern and a southern cold-water zone" (Ekman, 1953). This is true of the Salpidae except for the fact that there are no species confined to northern cold water. Therefore, it appears that water temperature is the primary limiting factor in the distribution of salps.

The majority of salps are cosmopolitan warm water plankters, although they may be carried into high latitudes from time to time. Only *Ihlea magalhanica*, *Thalia longicauda*, *Helicosalpa komaii*, and *Cyclosalpa strongylenteron* have been reported as restricted to certain oceanic regions. According to Apstein (1894, 1906) and Thompson (1948), *I. magalhanica* is restricted to the cool waters of the southern hemisphere; this is also true of *T. longicauda* according to Apstein, but Sewell (1953) reported one specimen from the northern Arabian Sea. *H. komaii* has been reported only from Japan (Komai, 1932) and the central Pacific (Yount, 1954), and *C. strongylenteron* only from the eastern Pacific (Berner, 1955), but both probably will be found to occur in the Indian and Atlantic oceans as well. Table 1 lists salp distribution by species as reported by Pacific investigators.

The remaining species of salps have been reported from the Atlantic, Indian, and Pacific oceans, except for *Ihlea punctata*, which has not yet been found in the Indian Ocean although it probably occurs there. Even the continents of South America and Africa do not prevent the transport of salps from one ocean to another, inasmuch as Herdman (1888) reported *Iasis zonaria* and Apstein (1906) listed *Salpa maxima* and *S. fusiformis* from the Straits of Magellan, and Apstein (1906) showed that *S. maxima*, *S. fusiformis*, *Metcalfina hexagona*, *Thalia democratica*, *T. longicauda*, *Pegea confoederata*, *Ia. zonaria*, and, of course, *Ih. magalhanica* had been captured at the region of the Cape of Good Hope or in more southerly waters. Salps are carried far into northern waters also (see Ihle, 1935), but probably cannot be carried alive into the Arctic Ocean.

With the exception of the four species mentioned above, then, it can be stated that the Salpidae is a family of cosmopolitan

TABLE 1
DISTRIBUTION OF SPECIES OF SALPIDAE (EXCEPT *I. magalhanica* AND *T. longicauda*)

SPECIES	ATLANTIC	INDIAN	JAPAN	PHILIP-PINES	EAST INDIES	AUS-TRALIA	N. E. PACIFIC	CENTRAL PACIFIC	EAST PACIFIC
Cyclosalpa pinnata	+	+	+	+	+	+	+	+	−
C. affinis	+	+	+	−	−	+	+	+	+
C. floridana	+	+	−	−	+	+	−	+	−
C. bakeri	+	+	+	+	+	+	+	+	+
C. strongylenteron	−	−	−	−	−	−	+	−	+
Helicosalpa virgula	+	+	−	−	−	+	−	+	−
H. Komati	−	−	+	−	−	−	−	+	−
Brooksia rostrata	+	+	−	+	+	+	−	+	−
Ihlea punctata	+	−	+	−	+	−	−	+	−
Salpa fusiformis	+	+	+	+	+	+	+	+	+
S. maxima	+	+	+	+	−	+	+	+	+
Weelia cylindrica	+	+	+	+	+	+	+	+	+
Ritteriella amboinensis	+	+	+	+	+	+	−	+	−
R. picteti	+	+	+	−	+	+	+	+	−
Metcalfina hexagona	+	+	−	+	+	+	−	+	+
Thetys vagina	+	+	+	+	+	+	+	+	+
Pegea confoederata	+	+	+	+	+	+	+	+	+
Traustedtia multitentaculata	+	+	+	−	+	+	−	+	−
Thalia democratica	+	+	+	+	+	+	+	+	−
Iasis zonaria	+	+	+	+	+	+	+	+	+

oceanic plankton organisms in the circumglobal warm water zone.

Seasonal, Latitudinal, and Longitudinal Variation

Cruise 5 was carried out during June, July, and August of 1950, the northern summer, and cruise 8 was carried out during January, February, and March of 1951, the northern winter. A comparison of the two cruises should reveal seasonal variations, if any are present; therefore, an analysis of variance was calculated to determine seasonal differences. Longitudes and latitudes were analyzed simultaneously with seasons by the method described by Snedecor (1946: 304–309). Volumes were used as the variate rather than numbers, as volume is a better measure of the organic material in a plankton tow.

King and Demond (1953), who studied the total zooplankton volumes on cruises 5 and 8, demonstrated no significant first- and second-order interactions and no significant differences between longitudinal means, but did demonstrate significant differences between the means for seasons and for latitudes: No significant differences for the salp volumes, however, were demonstrated between either of the means for longitudes, for seasons, or for latitudes. Neither are there significant differences in the first- and second-order interactions, except that between longitudes and seasons. Therefore, there is probably ($P = 0.03$) an interaction between longitudes and seasons that produced the observed differences in volumes of salps at the 11 compared latitudes. I am unable to offer any conjectures to explain this interaction; it must be borne in mind, however, that the analysis is based on a few samples and that the variation in distribution of plankters, as well as the limited sampling by towing, could easily distort the resultant picture. This analysis supports the conclusion noted earlier under the comparison of volumes of salps and of the remaining zooplankton, i.e., that variation in salp volume does not necessarily relate to that of the total zooplankton, and was very different in the samples studied.

Relationship of Salps to Oceanic Currents

Comparison of the species at each station of cruises 5 and 8 (at the latitudes of Figs. 1 and 2, exactly listed by King and Demond, 1953), with the current system of the central Pacific (Cromwell, 1954) showed that there were only three species of salps found in but one current on these cruises. On cruise 5, 172° W., for example, *Cyclosalpa bakeri* and *Ihlea punctata* were found only in the South Equatorial Current. Examination of the distribution of these species on other longitudes and cruises, however, shows that they were found at some station in all other currents as well. This is true also of most other species, as they occurred in one longitude or another or on one cruise or another in all of the principal currents. Only three species were restricted in the central Pacific, *Cyclosalpa affinis*, *C. floridana*, and *Metcalfina hexagona*, the first and last of which occurred in only one current; *C. floridana* occurred in only two currents. *C. affinis* occurred at no other station of the two cruises and only three specimens were captured. It is thus an uncommon species in the POFI collections studied, and probably cannot be considered as an indicator of this current. *M. hexagona* was also captured at only one station on only one cruise, but occurred in fair numbers (43 specimens). On other cruises, however, it is not an extremely rare species, since in the collections of animals larger than 5 cm. from all POFI cruises, it occurs in at least five samples. It cannot be considered an indicator species, then, on the basis of only one record on one cruise, particularly since only 32 stations of cruise 8 were examined. *C. floridana* was also a relatively uncommon species on these cruises and thus cannot be regarded as an indicator species.

Ihlea magalhanica, a species not found in the POFI collections, has been considered a probable indicator species of colder water advancing northerly in the Australian area (Thompson, 1948). Thompson stated that *Ih. magalhanica* "is one of the salp species which has a low tolerance of warm water conditions," and that it "will therefore probably be useful as an indicator of any northern extension of the colder type of water conditions which may from time to time occur." In the same report, however, he stated, "there is . . . no evidence of a genuine cold water influence, even in Tasmanian waters, although in the latter region species which are characteristic of warm-temperature waters as well as of circumtropical waters are those most usually found (e.g., *Ihlea magalhanica*, *Iasis zonaria* and *Thetys vagina*)." *Ih. magalhanica* was earlier reported by Apstein (1894, 1906) in the Antarctic, westerly and southwesterly of the southern point of Africa, and in the Straits of Magellan, in water with a temperature range from 0° to 12.3° C. Thompson (1948), however, reported the temperature range of this species as between 11.6° and 22.25° C. This species, therefore, should perhaps be regarded as a eurythermal, rather than a stenothermal, cool water form and its usefulness as an indicator of cold water currents perhaps is much less than was thought previously. Its presence in water with a temperature of 22.25° C. may be exceptional, i.e., it may have been transported into such water but may not be long viable there, or the animal(s) may have been actually in a deep cool layer of water at this station. Thompson did not explain the situation, however.

Therefore, it can be stated that all salps captured on cruises 5 and 8 can be expected to occur in all currents in warm latitudes and that they are not satisfactory indicator species for these latitudes. Three uncommon species might possibly be true indicator species, but this is doubtful.

ECOLOGICAL NICHE OF SALPS

When one contemplates niches in the marine plankton community, it becomes clear that there are relatively fewer niches in the plankton than there are in the benthos or in land communities ("The 'niche' of an animal means its place in the biotic environment, *its*

relations to food and enemies," Elton, 1927: 64). For example, in the warm water epipelagic zone, the species are remarkably similar the world over (this is true of salps and it is undoubtedly true of other plankters as well); but even an oceanic island, such as Oahu for example, doubtlessly possesses many times more species of organisms than the plankton of the whole, vast epipelagic zone in the warm water belt of the world. This observation, I think, reflects the general paucity of niches and habitats in the pelagic oceanic environment, due most likely to the remarkable uniformity of the physical conditions and to the lack of shelter there.

The Salpidae is one of the many groups of planktonic filter feeders; salps feed by straining the water which passes through their body cavities by means of mucus strings secreted chiefly from the endostyle (see Ihle, 1935, 1937–39). Notwithstanding differences in structural and physiological mechanisms associated with filter feeders, they catch and consume, in general, the same organisms as other pelagic tunicates (pyrosomids, doliolids, and to some extent appendicularians), some pteropods, some copepods, and perhaps other constituents of the plankton, since the food of all these organisms is captured by simply filtering the water. It has long been known that salps are not selective feeders and that methods and mechanisms for feeding are similar in all species thus far studied (see Ihle, 1935, 1937–39).

In order, then, to attempt a segregation of the niches of the various species of salps, an analysis of the gut contents of all species reported here was undertaken, and observations were made as to their probable predators. Various salp species were chosen from different latitudes, longitudes, and cruises in order to have a respresentative sample. This resulted in the following observations: the food of all specimens and species of salps is remarkably similar throughout the area studied; and the food of all salp species within any one plankton sample is the same.

SUMMARY OF THE RESULTS OF THE GUT CONTENT ANALYSES

very common food	unidentified matter
	diatoms
	dinoflagellates
common food	silicoflagellates
	radiolarians
	coccolithophores
	foraminiferans
rare food	small crustaceans (chiefly copepods)
	gastropod larvae
	pteropods
	annelids
	fish eggs

Enemies of salps under natural conditions are unknown. Observations that may provide a clue on this situation, however, have been made in the plankton samples. There is a certain amount of conjecture in such deductions because carnivorous animals can be expected to bite whatever is near them during the death struggle after formalin is added to a plankton sample. Nevertheless, animals that contain salps in their digestive tracts or that hold to salps in the preservative may be their enemies in nature. Obviously, a chaetognath could be predaceous on *Thalia democratica* but not on *Thetys vagina* except in its young stage. The following animal types have been observed holding onto salps in preserved plankton tows: chaetognaths, heteropods, coelenterates, and crustacea (chiefly copepods and hyperiid amphipods). No planktonic animals have been observed to contain salps in their guts, but special study was not performed with this object in mind. Thompson (1948: 160) reported *Salpa fusiformis* from stomachs of blue cod from New Zealand, and Reintjes and King (1953) reported *Pyrosoma* sp., unidentified salps, and unidentified tunicates other than these in the gut contents of yellowfin tuna (*Neothunnus macropterus*). Fraser (1949) reported *I. asymmetrica* (= *I. punctata*) and *Dolioletta gegenbauri* from a herring stomach, and that salps were reported as part of the

food of the pelagic turtle, *Thalassochelys caretta*. I have recently identified five specimens of *Thalia democratica* agg. from the gut contents of a fish, *Chaetodon unimaculata*, taken by rotenone poison off Honolulu at a depth of about 25 feet. This fish contained many appendicularians also, probably of the genus *Oikopleura*. Other than this, no information is available as to the enemies of salps.

Because there is no apparent selection of food, and because the food, feeding methods, and mechanisms are similar in all species of salps, and because enemies are evidently similar, all salp species appear to occupy similar niches (with some slight differences between salps of different sizes in their ability to handle the larger food organisms). Inasmuch as many species of salps have been found together in one plankton tow (up to 9 in the POFI collections studied), and all species in a plankton tow can be assumed to be subject to at least approximately the same enemies and to the same environmental conditions, it can be stated that all salps apparently occupy similar niches simultaneously, and are, for all practical purposes, ecological equivalents. This statement doubtless applies to many other plankters as well as to salps: Any one niche in the plankton community of the epipelagic zone of tropic oceanic waters may be occupied simultaneously by many species. To illustrate, a few specimens of doliolids and pyrosomids have been subjected to a gut content analysis, and these animals also contained generally the same food organisms as the salps. Appendicularians, although to some extent feeding on similar food as other planktonic tunicates, are probably more restricted in the type of food they can handle as a result of their highly modified food-catching mechanisms, and are thus probably limited in their equivalence with other pelagic tunicates. It is probable that predaceous plankters such as chaetognaths, heteropods, coelenterates, and some crustacea found in tropic epipelagic waters also occupy similar niches simultaneously.

Marshall and Orr (1953) briefly discussed the concept of the niche (including the concept of habitat in the same term) in regard to the plankton community and pointed out that ". . . it is at first sight hard to understand how different ecological niches can be available in a medium so constant as sea water." They suggested that differences in niches among plankters may be found in the different foods on which the plankters depend. Such a suggestion may be applicable to plankters found in coastal and temperate waters, but for tropic oceanic waters it seems scarcely applicable, at least to the salps and undoubtedly also to many other plankton animals. To be certain of this niche equivalence, it would be desirable to know the vertical distribution of the captured animals, but the tows studied cannot furnish such information, as they were made with an open net. Conjectures have been made as to the causes and results of this apparent niche equivalence of many species, but they are not included in this report. They have resulted in a study of species variety in Silver Springs, Florida, in which factors controlling the numbers of species are discussed (Yount, 1956).

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Some Trematodes of Fishes from the Central Equatorial Pacific

EDWIN S. IVERSEN[1] and EARL E. HOVEN[2]

THIS REPORT is based on a collection of trematodes from marine fishes captured in the vicinity of the Line Islands. All the trematode species listed are believed to constitute first records from this area, and some are first reports from new hosts. Collections were made in 1955 during exploratory tuna fishing by trolling and longlining. These fishing surveys were carried out by Pacific Oceanic Fishery Investigations (POFI), a branch of the U. S. Fish and Wildlife Service, as one phase of a program designed to determine the distribution and abundance of tunas in the Pacific. The Line Islands from which this material was collected are: Christmas, Fanning, Washington, and Palmyra islands, and Kingman Reef. They extend in a northwesterly direction from 2° N. latitude, 157° W. longitude to 6° N. latitude, 163° W. longitude.

All specimens, except the hemiurids, were identified through the kind efforts of Dr. Harold W. Manter, Department of Zoology, University of Nebraska. Unfortunately facilities were not available aboard ship for proper preservation of such material; as a result many of the specimens were identified with difficulty and some could not be accurately identified. Dr. Donald C. Matthews, Department of Zoology, University of Hawaii, very kindly provided sections of the encysted didymocystid included herein. Thanks are extended to E. Dixon Stroup, POFI, for making the photographs used in this report. All collections have been deposited in the U. S. National Museum.

Order MONOGENEA

Family MICROCOTYLIDAE

Neothoracocotyle acanthocybii (Meserve, 1938)

SYNONYMS: *Gotocotyla acanthocybii* Meserve, 1938.

HOST: Wahoo, *Acanthocybium solandri* (Cuvier and Valenciennes).

LOCATION: Between gill filaments.

LOCALITY: Kingman Reef, 6° 20′ N., 162° 30′ W.

SPECIMENS: USNM Helm. Coll. No. 38132.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: *Acanthocybium solandri* from the Galapagos Islands.

DISCUSSION: Since these parasites are located between the gill filaments, they are found only by rather close scrutiny. Other duties while at sea prevented a careful record of the number of infected fish. The number of worms per host is probably large and the rate of infestation high. Hargis (1956), who has erected the genus *Neothoracocotyle*, reported the new combination.

Family CAPSALIDAE

Capsala poeyi (Vigueras, 1935) Price, 1938

SYNONYMS: *Tristomum poeyi* Vigueras, 1935.

HOST: Black marlin, *Makaira ampla*[3] (Poey).

LOCATION: Outside surface on isthmus and second dorsal fin.

LOCALITY: 04° 48′ N., 160° 37′ W. (vicinity of Washington Island).

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[3] Identification of the Pacific *M. ampla* was based on an unpublished key provided by Dr. William F. Royce. As this paper goes to press, it is apparent that there is considerable disagreement concerning the classification of the marlins.

SPECIMENS: USNM Helm. Coll. No. 38131.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: Reported from the same species of host off Havana, Cuba, by Vigueras (1935).

Capsala biparasitica (Goto, 1894) Price, 1938

SYNONYMS: *Tristoma biparasitica* Goto, 1894.

HOST: Yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel).

LOCATION: Firmly attached to carapace of copepods found in gills.

LOCALITY: 02° 14′ N., 159° 59′ W. (vicinity of Christmas Island).

SPECIMENS: USNM Helm. Coll. No. 38134.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: Goto collected this species of trematode from a copepod (*Parapetalus* sp.) on *Thynnus albacora* from Misaki, Japan.

DISCUSSION: The copepod involved in the present record is *Elytrophora* sp. A comparison of these host records is of particular interest because the trematode is a hyperparasite and because in each collection both the copepod hosts are caligid copepods and the fish hosts are closely related.

Family HEXASTOMATIDAE

Hexostoma grossum (Goto, 1894) Sproston, 1946

SYNONYMS: *Hexacotyle grossa* Goto, 1894.

HOST: Bigeye tuna, *Parathunnus sibi* (Temminck and Schlegel).

LOCATION: On gills.

LOCALITY: 02° 45′ N., 158° 05′ W.

SPECIMENS: USNM Helm. Coll. No. 38133.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: On gills of *Thynnus* sp. from Misaki, Japan (Goto, 1894); type host corrected to *Parathunnus sibi* and reported on gills of *Katsuwonus vagans* and *Thunnus orientalis*, and on *Seriola quinqueradiata* from Japan (Ishii and Sawada, 1938).

Order **DIGENEA**

Family HEMIURIDAE

Hirudinella marina Garcin, 1730

SYNONYMS: Nigrelli and Stunkard (1947) include a very lengthy list of possible synonyms of this species.

HOST: Yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel).

LOCATION: In stomach.

LOCALITY: 06° 20′ N., 162° 30′ W. (vicinity of Kingman Reef).

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: Nigrelli and Stunkard (1947) include a long list of hosts, mostly of scombriform fishes, including *N. macropterus* from C. San Lucas, Lower California, Pacific.

DISCUSSION: In the course of the examination of stomach contents of yellowfin and bigeye tuna from the central Pacific, King and Ikehara (1956) encountered large muscular trematodes. They report an infection rate of 32 per cent for 166 bigeye and 26 per cent for the 439 yellowfin they examined. Since Nigrelli and Stunkard recognize only two species of *Hirudinella*, one in the wahoo, *H. ventricosa*, and one in other hosts, *H. marina*, it is very likely that these worms belong to the latter species.

Hirudinella ventricosa Pallas, 1774

SYNONYMS: Nigrelli and Stunkard (1947) list nine possible synonyms.

HOST: Wahoo, *Acanthocybium solandri* (Cuvier and Valenciennes).

LOCATION: Stomach.

LOCALITY: Christmas, Fanning, Washington, Palmyra islands, and Kingman Reef.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: *Acanthocybium solandri* in the Atlantic and Pacific; from the Pacific it has been reported from Panama, Mexico, Equador, and the Marianas Islands (Nigrelli and Stunkard, 1947).

DISCUSSION: Nigrelli and Stunkard (1947) have made a thorough study of this genus and

regard all *Hirudinella* reported from the wahoo as belonging to a single species, *H. ventricosa* Pallas. In an examination of 220 wahoo stomachs from the Line Islands, Iversen and Yoshida (1957) found a 98.2 per cent infection of these parasites. The hosts ranged in size from 108 to 172 cm. and as many as 17 of the worms were found in a single stomach, with 2 per host occurring most frequently.

H. ventricosa may be present elsewhere in the Pacific, for Edmondson (1946) states in respect to the Hawaiian region, that "An undetermined species of trematode commonly occurs in the stomach of the Ono, *Acanthocybium solandri* (Cuvier)." These flukes were about 1 inch long when partially contracted. Kishinouye (1923) in speaking of wahoo from Japan says "A large distomum, about 8 cm. in length, is almost always found in the stomach."

FIG. 1. Photograph of encysted *Didymocystis acanthocybii* on the side of the head of a wahoo (gill cover removed).

Family DIDYMOZOONIDAE

Didymocystis acanthocybii
Yamaguti, 1938

HOST: Wahoo, *Acanthocybium solandri* (Cuvier and Valenciennes).

LOCATION: Base of gill arches and on operculum.

LOCALITY: Christmas, Fanning, Washington, Palmyra islands, and Kingman Reef.

SPECIMENS: USNM Helm. Coll. No. 38171.

PREVIOUSLY REPORTED HOSTS AND LOCALITIES: At base of gill arch of *Acanthocybium sara* (Lay et Bennett); Pacific, Japan, Yamaguti (1938).

DISCUSSION: Of the 104 wahoo examined, 53 revealed conspicuous cysts of this parasite (Fig. 1). The fish ranged in size from 86 to 174 cm., and specimens of all sizes within this range were found to be infected. Figure 2 shows the relationship of the paired worms within the cyst.

Didymocystis sp.

HOST: Yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel).

LOCATION: On gill filaments.

LOCALITY: 00° 28′ N., 157° 48′ W.

SPECIMENS: USNM Helm. Coll. No. 38172.

DISCUSSION: The condition of specimens does not permit identification, but they resemble *D. wedli* Ariola, 1902, more closely than others. The infection rate of yellowfin is probably not high.

DISCUSSION

Concomitant studies of hosts and parasites from different geographic areas have been reviewed by Metcalf (1929) and Manter (1955), who have presented considerable evidence that parasites reflect the distribution and way of living of their hosts. A basic problem in the study of some pelagic fishes is to determine whether the population of each important species is continuous throughout its range or whether it is composed of a number of independent or semi-independent

units. In this connection these records, especially of Monogenea which are host specific, are of interest. *Capsala biparasitica* from yellowfin tuna in Japan and the Line Islands, *Hexastoma grossum* from bigeye in Japan and the Line Islands, *Neothoracocotyle acanthocybii* from wahoo in the Line and Galapagos islands, and *Capsala poeyi* from the black marlin in the Atlantic and Pacific, all suggest that these stocks of fish are not, or were not, completely independent.

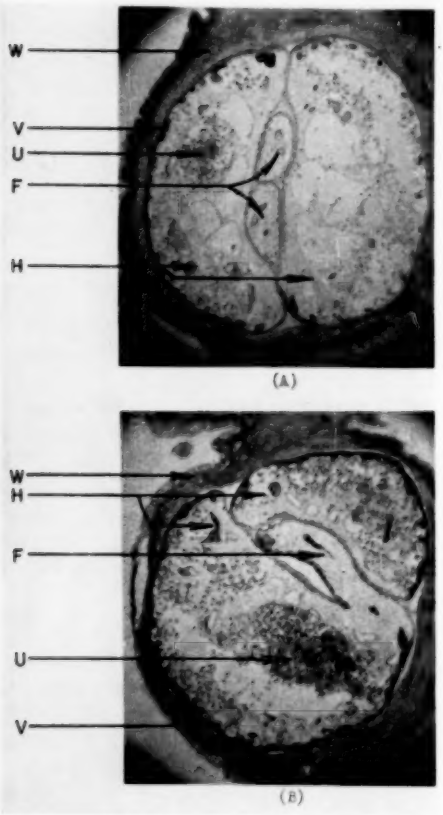

FIG. 2. *Didymocystis acanthocybii*. (A) Photomicrograph of a cross section through two trematodes showing the host tissue (W) surrounding the cyst, the forebodies (F), the hindbodies (H), the uterus (U), and vitellarium (V) of each. (B) Photomicrograph of a section through two trematodes showing the forebody of one in sagittal section. 10 microns.

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Two New Doliolids from the Eastern Pacific Ocean[1]

TAKASI TOKIOKA[2] and LOE BERNER[3]

THE MATERIAL upon which this report is based was collected during the Shellback Expedition carried out by Scripps Institution of Oceanography in 1952. This expedition conducted its work in the east central Pacific Ocean off Central America and northern South America. While the authors were examining the many plankton samples they found two unusual doliolids. These specimens were from samples taken in the waters off Peru. The specimens are all gonozooids; and although they are not in a good state of preservation, the arrangements of muscles, alimentary organs, and gonads have been determined by close examination, after staining with Rose Bengal. One of the two forms belongs to the genus *Doliopsoides* established by Krüger (1939: 138–139). This genus, in the appearance of the musculature, shows an intermediate state between the Cylomyaria and the Desmomyaria. The other form belongs to the genus *Doliolina*. Both forms differ from any previously described species known to us and we consider them to be new species.

This is the first reported occurrence of the genus *Doliopsoides* from the Pacific Ocean and, indeed, is the first report of the genus since it was described by Krüger. At present the known distributions of *D. horizoni* and of *D. undulatum* are limited to only two stations.

[1] Contribution from Scripps Institution of Oceanography, New Series No. 975. This work was supported in part by grants from the Rockefeller Foundation and the Office of Naval Research. Manuscript received October 23, 1956.

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[3] Scripps Institution of Oceanography, University of California, La Jolla, California.

Doliopsoides horizoni new species
Fig. 1

Three gonozooids are dealt with here. All were found in the sample from station SB-115 located at 8° 16′ S., 83° 42′ W. They are 3.9 mm., 4.6 mm., and 5.2 mm. in length. One additional specimen was taken at station SB-118 located at 9° 49′ S., 83° 02.5′ W. The body is roughly barrel-shaped with the oral aperture at the anterior end and the atrial aperture at the posterior end of the body. Both apertures are rather wide and fringed with a narrow margin which is, apparently, without lappets. The test is of moderate thickness, very soft, and easily stripped from the body. The mantle is extremely thin and delicate. The muscles are rather narrow, especially I, VII, and VIII. Muscles I through IV and VIII form complete hoops. The first and seventh intermuscular zones are narrow while the second is quite wide. Muscle V runs obliquely from the posteroventral to the anterodorsal side and is widely interrupted at the middorsal line. Each dorsal end of muscle V turns backwards for a short distance and then runs obliquely to the posteroventral side. These parts represent muscle VI and are arranged parallel to muscle V. They are not continuous across the mid-ventral line. There is a short section on each of the ventral ends of muscle VI which turns slightly forward. Each of the ventral ends of muscle VII passes external to muscle VI on the side of the body. Muscle VII ends slightly below the mid-ventral line, just after crossing muscle VI. In addition to these muscles there are two narrow, short connecting muscles (lateral longitudinal muscle, l.l.m.) between muscles IV

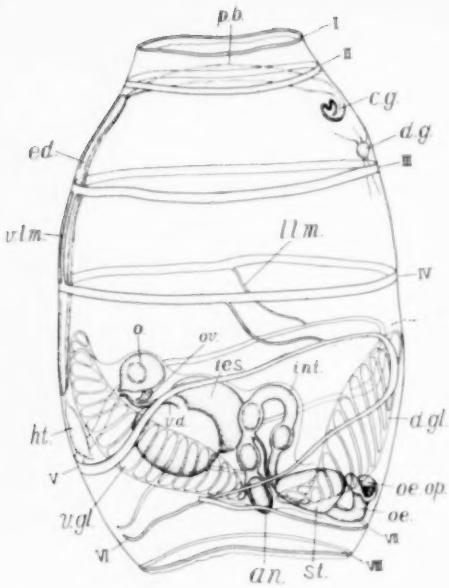

FIG. 1. *Doliopsoides horizoni* n. sp., gonozooid from left side. I–VIII, circular body muscles; *an.*, anus; *c.g.*, ciliated groove; *d.g.*, dorsal ganglion; *d.gl.*, dorsal gill; *ed.*, endostyle; *ht.*, heart; *int.*, intestine; *l.l.m.*, lateral longitudinal muscle; *o.*, mature ovum; *oe.*, oesophagus; *oe.op.*, oesophageal opening; *ov.*, ovary; *p.b.*, peripharyngeal band; *st.*, stomach; *tes.*, testis; *v.d.*, vas deferens; *v.gl.*, ventral gill; *v.l.m.*, ventral longitudinal muscle.

and V, one on each side of the body. These muscles extend from just below the midlateral portion of muscle IV obliquely upward, joining muscle V just above the midlateral line. Another narrow longitudinal muscle (ventral longitudinal muscle, v.l.m.) connects muscles III and IV along the midventral line.

The endostyle (ed.) is long and rather thick although its consistency does not seem to be compact. Anteriorly it begins just behind muscle II and extends posteriorly to slightly beyond the middle of the fourth intermuscular zone. The anterior margins of the peripharyngeal bands (p.b.) project slightly in front of muscle II. The ciliated groove (c.g.) is located near the middle of the second intermuscular zone, the dorsal ganglion (d.g.) is in the same zone near muscle III. The gill consists of a dorsal (d.gl.) and a ventral pair (v.gl.) of lamellae. It extends dorsally to the level of the ends of muscle V and ventrally to the middle of the fourth intermuscular zone or slightly anterior to it. The dorsal and ventral lamellae approach just above the juncture of muscle VI and VII. The gill bears in all 30 to 40 elongate stigmata.

The oesophageal opening (oe.op.) is located on the dorsomedian line near muscle VII, the oesophagus (oe.) itself is strongly curved. The stomach (st.) is situated vertically and in outline roughly forms an elongate triangle with the pyloric portion the narrowest. The intestine (int.) forms a U-shaped loop in the saggital plane of the body which ends with the anus (an.) near the pyloric end of the stomach. The proximal portion of the loop is somewhat thinner than the other portions and it is not certain whether this represents a hind stomach. The formation of fecal pellets was observed in all three specimens. Krüger in his description of *D. meteori* mentioned the formation of "Kotballen" in the intestine. There is a thin but distinct vessel connecting the pyloric portion of the stomach with the middle of the ventral branch of the intestinal loop. The ovary (ov.) is situated just dorsal to the posterior end of the endostyle and slightly to the right of the median line. In one specimen the ovary contains a large mature ovum (o.). The oviduct is so short as to be practically absent. The testis (tes.) is located between the ovary and the intestinal loop. It consists of two spherical lobes. The vas deferens (v.d.) is short but distinct, and extends from the testicular lobes to near the ovary, probably in the region of the female genital pore. The heart (ht.) lies between the posterior end of the endostyle and muscle V.

REMARKS

This form is evidentally very closely related to *Doliopsoides meteori* (Krüger, 1939). Krüger's genus and species were described from a

plankton sample taken at Meteor station 267, in the layer between 400 and 200 meters, in the Atlantic Ocean off Cape Verde. Our specimens differ distinctly from Krüger's species in the following points: (1) The ventral longitudinal muscle connects muscles III and IV rather than muscles II and III as in *D. meteori*. (2) The oesophageal opening is situated on the middorsal line just anterior to muscle VII while in *D. meteori* it is located centrally on the level with muscle VI (see Krüger's fig. 87). (3) Muscle VI is interrupted at the mid-ventral line in *D. horizoni* while it is continuous in *D. meteori*. In one part of Krüger's text figure the ventral ends of muscle VII are shown as if they passed internally to muscle VI, in another as if they passed externally to muscle VI. This apparent error may have been due to the poor condition of his specimens, but makes it impossible to compare the two species on this point. The specific name *horizoni* refers to the vessel which carried the Shellback Expedition; this follows Krüger's lead in naming his species after the ship from which it was taken. Comparing the structures of *D. meteori* and *D. horizoni* we have come to the conclusion that the genus *Doliopsoides* may be defined as follows:

Doliopsoides Krüger 1939: oozooid, trophozooid, and phorozooid unknown.

Gonozooid: The gonozooid is barrel-shaped with eight nearly hooplike muscles. Muscles I through IV and VIII form complete hoops while V, VI, and VII are interrupted. In addition to the circular muscles there are some longitudinal muscles, which are variously placed on the body. Both the ciliated groove and the dorsal ganglion are situated in the second intermuscular zone. The gill consists of a dorsal and a ventral pair of lamellae. The gonads are located anteroventrally to the alimentary organs. Although there are some rather marked differences between our specimens and Krüger's description we do not feel they warrant more than specific treatment. The type species is *Doliopsoides meteori* Krüger 1939.

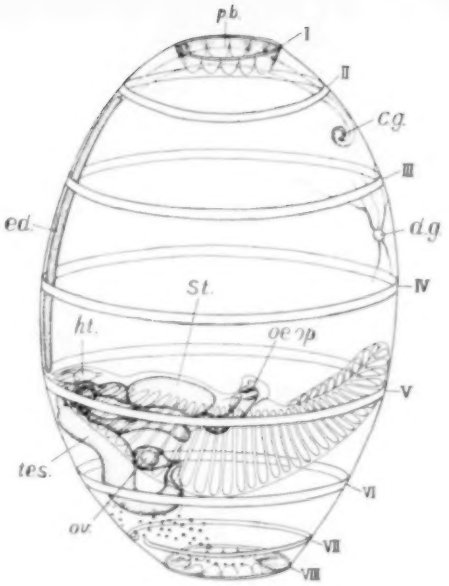

FIG. 2. *Doliolina undulatum* n. sp., gonozooid from left side. For abbreviations see Figure 1.

Doliolina undulatum new species
Fig. 2

This species is represented by five gonozooids from station SB-115 and four gonozooids from station SB-94. The location of SB-115 is given above, SB-94 was located at 9° 58.5′ S. and 95° 01′ W. These latter specimens are in a very poor state of preservation and we will deal here only with those from SB-115. They range from 3.3 to 4.6 mm. in length. The test is of moderate thickness but very soft and easily stripped from the body. The general appearance of the body and the arrangement of the eight circular muscles is quite similar to *D. intermedium* (Neumann, 1906), which occurs frequently in the Shellback area. A most striking difference is the interruption of muscle VII at the mid-ventral line in this new species. The mantle is thin. The muscles are narrow, especially I and VIII. Muscle VII is also somewhat narrower than the rest.

The endostyle (ed.) is very long, extending anteriorly nearly to muscle II and posteriorly to the anterior margin of muscle V. The anterior margin of the peripharyngeal band (p.b.) extends forward almost to muscle I. The ciliated groove (c.g.) is situated near the middle of the second intermuscular zone. The dorsal ganglion is situated in the third intermuscular zone, its posterior edge is at the middle of the zone. The gill septum extends from the middle of the fourth intermuscular zone dorsally, obliquely back to the level of muscle VI and then obliquely forward to the level of muscle V ventrally. It bears 30–40 pairs of elongate stigmata.

The oesophageal opening (oe.op.) is located approximately on the longitudinal axis near the posterior margin of muscle V. The stomach (st.) is located vertically at the same level;, it is roughly rectangular in outline, slightly curved with the convex side forward. The intestine forms a simple loop and ends with the anal opening near the cardiac portion of the stomach and on a level with the middle of the fifth intermuscular zone. The hind stomach and mid-intestine are rather distinctly marked. There appears to be a thin short vessel connecting the pyloric end of the stomach with the middle of the posterior branch of the intestinal loop.

The ovary (ov.) is situated on a level with muscle VI, slightly to the right of the mid-ventral line. The testis (tes.) is somewhat sausage-shaped. It extends, with an undulating course, along the left side of the body between muscle V and the genital pore. There are a number of small cell groups scattered over the ventral half of the sixth intermuscular zone and on a small portion of the seventh intermuscular zone.

REMARKS

The oozooid, trophozooid, and the phorozooid of this species are unknown.

Gonozooid: At a glance the present new species may be confused with *D. intermedium* (Neumann, 1905: 211). The longer endostyle in *D. undulatum* can be used as a good indicator to distinguish it from *D. intermedium*. In most of the specimens of *D. intermedium* collected in the Shellback area the endostyle reaches only slightly beyond the middle of the second intermuscular zone and its posterior end is located near the middle of the fourth intermuscular zone. The mid-ventral interruption of muscle VII is also unique in *D. undulatum*. *Dolioletta mirabilis* is the only doliolid, outside the genus *Doliopsoides*, which has an interrupted muscle band. In this case there is a mid-ventral interruption of muscle VI below the gut. The characteristic appearance of the testis, from which the specific name of the new species has come, is also unique and serves to separate the species from all others in the genus.

The following material, upon which part of the descriptions herein are based, has been deposited in the U. S. National Museum:

1. *Doliopsoides horizoni*, gonozooids, SYNTYPES, 3 specimens USNM Cat. No. 11368. These specimens were poorly preserved and it was felt impossible to designate a type from among them. They are all from station SB-115.

2. *Doliolina undulatum*, gonozooid, HOLOTYPE, 1 specimen USNM Cat. No. 11369.

3. *Doliolina undulatum*, gonozooids, PARATYPES, 4 specimens USNM Cat. No. 11370.

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A New *Hedyotis* from Kauai, Hawaiian Islands

BENJAMIN C. STONE and IRWIN LANE[1]

THE MOST RECENT revision of the Hawaiian species of *Hedyotis* (Rubiaceae) is that of F. R. Fosberg (1943), who treated all the Polynesian species, describing many new forms. The genus as considered by Fosberg includes, with good reason, the segregate genera *Oldenlandia* L., *Gerontogea* Cham. and Schlecht., *Kadua* Cham. and Schlecht., *Diplophragma* Meisn., as well as *Gouldia romanzoffiensis* A. Gray, a species not properly in *Gouldia*.

The type species of *Hedyotis* is *H. auricularia* L., which forms also the basis of the subgenus *Hedyotis*. This subgenus contains the species native to southern Asia which have axillary inflorescences, indehiscent or septicidal fruits, and usually a depressed habit of spermacoccoid appearance. The sections and subgenera found in Polynesia are as follows.

Subgenera: *Oldenlandia*, including only *Hedyotis biflora* L., a wide-spread plant of tropical Asia, the islands of the Indian Ocean, Malaysia, Micronesia, Melanesia, Fiji, and, in Polynesia, Samoa and Tonga.

Diplophragma, of southern and western Polynesia, eastern Melanesia, and Micronesia, but not known from Hawaii.

Kadua, two variable species confined to the Hawaiian Islands.

Oceanica, comprising the single species transferred from *Gouldia*, and present only in southern and central Polynesia.

Polynesiotis, with 19 species, principally developed in Hawaii, with a secondary center in southern Polynesia. This subgenus has five sections: *Wiegmannia*, *Protokadua*, *Gouldiopsis*, *Bikkiocarpa*, and *Austrogouldia*.

The new species described herein fits well into the subgenus *Polynesiotis* and into the section *Wiegmannia*. However, it differs in two of the key characters employed in Fosberg's key to the subgenera. First, in our specimens the stigmas are consistently quadrifid, not bifid; second, the width of the corolla tube is not "much less than ⅓ the length" of the corolla tube, as the key states, but is in some cases as wide as it is long. At first glance the inflorescences seem axillary, but on closer inspection it can be seen that they are strictly terminal; however, the first axillary bud below the inflorescence grows into a stem (or in some cases both of the two axillary buds), and these in turn eventually terminate in inflorescences; this gives the plants an aspect of branching which might be termed subscorpioid.

Within the section *Wiegmannia* of the subgenus *Polynesiotis*, our specimens are evidently very closely related to *Hedyotis littoralis* (Hbd.) Fosberg, a striking and characteristic species distinguished by its fleshy leaves, which are closely set on a decumbent corky stem, and by its habitat on cliffs or rocks close to the sea. It is known mostly from Molokai and Maui; although there exist specimens from Kauai, Oahu, and Hawaii, they are old (Hillebrand's from Kauai and Oahu, Abbé Faurie's

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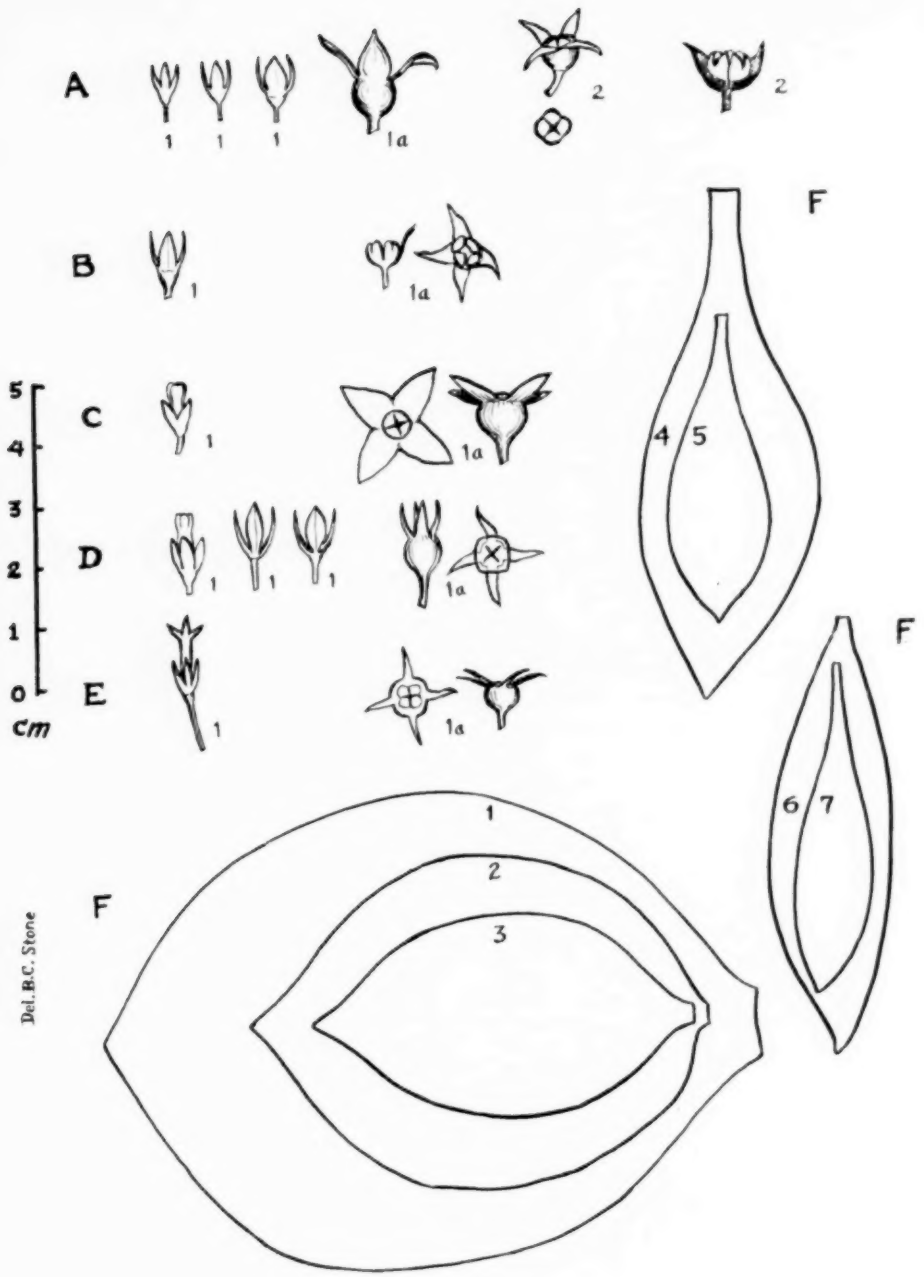
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Del. B.C. Stone

from Hawaii), and there have been apparently no other collections in these localities since the original specimens were taken. Fosberg says "the plant has become quite rare, except on the windward coast of east Molokai. I searched for it without avail at Hanalei, Kauai, in 1935. It has not been found on Oahu since Hillebrand's time."

Our specimens exhibit many features characteristic of *H. littoralis*, including its habitat preference, but in flower color, corolla shape, and fruit shape they show clear-cut differences. The general aspect of both species is very similar, and the two are both quite different in this regard from the majority of the other Hawaiian species of *Hedyotis*.

The following changes in the keys should be made to accomodate this new species. In the key to the subgenera (Fosberg, 1943: 19), under the second number 2, read: "Corolla fleshy or at least thickened, salverform, anthers included or the tips barely exserted, style shorter than or subequal with tube, bifid or quadrifid (lobes may cohere), seeds angular.....3." Under the second 3, read: "Inflorescence terminal, terminal and axillary, or seemingly axillary but terminating the main stem, the branch below arising from the first axillary bud(s).....4." Under the second 4, read: "Width of corolla tube usually much less than ⅓ the length, but in some as wide as long; cyme usually many-flowered; fruit dry, or if fleshy, calyx lobes much over 1 mm. long.....*Polynesiotis*."

In the key to the sections of *Polynesiotis* (Fosberg 1943: 23), under the first 2, read: "Calyx lobes foliaceous, longer than hypanthium in flower, conspicuously accrescent in fruit, distinctly nerved, subscabrous in some; corolla limb not quadrangular in bud, inflorescence usually quite glaucous..... *Wiegmannia*."

In the key to the species of section *Wiegmannia*, insert in place of the lead to *H. littoralis*: "2. Leaves, bracts, calyx lobes, and ovary fleshy; leaves mainly sub-basal.....3.

3. Corollas white, the tube two or three times longer than wide; fruits subglobose, crowned by the persistent enlarged calyx ..... **H. littoralis**

3. Corollas green, the tube as long as wide or up to twice as long as wide; fruits usually conspicuously flattened, the persistent enlarged calyx lobes spreading from the equatorial plane of the fruits... ..... **H. St.-Johnii**"

DESCRIPTION

Hedyotis St.-Johnii B. C. Stone and I. Lane sp. nov. (Subgen. POLYNESIOTIS sect. WIEGMANNIA)

Suffrutex parvus non- vel pauci-ramosus decumbens in scopuloris saxatilis maritimis Kauaiensibus habitans, caulis lignosus longitudinaliter sulcatus, petiolis connatis et fasciis suberosis inter foliosis ambis cinctis, folia opposita dense conferta irregulariter elliptico-acuminata ad apicem saepe asymetrice curvata in vivo subcarnosa convexa supra fusco-viridia et nitida infra subglauca pullovenosa, bases foliorum lati-petiolatae vel alatae bases bini connatae, laminae 5–14 cm. longae 2–5.5 cm. latae marginibus integribus, superficies foliorum (et bracteorum et calicorum) minute albo-scabratus, costa nervique leviter prominulentes, nervi laterales 4–10 arcuatim adscendentes vix anastomosantes (rete venularum conspicuum sed minutum), folia emortui persistentes vestirentes, inflorescentia stricte terminalis pauci-ramosa usque 17 cm. longa remote bracteata thyrsoidea tripartite cymosa, ramus quisque dichasius fere

FIG. 1. A–F, *Hedyotis littoralis*. A-1, Faurie 374, Molokai; 1, calyces, 1*a*, fruit; 2, Faurie 375, Halawa, Hawaii, fruits. B, Skottsberg 800, East Maui, 250 m. alt.; 1, calyx, young; 1*a*, fruit. C, Degener and Nitta 9430, Wailau, Molokai; 1, bud; 1*a*, fruit. D, same, 2d sheet; 1, buds and young calyces; 1*a*, fruit. E, Forbes 237-M, Keaneae, East Maui; 1, flower; 1*a*, fruits. F, leaves, 1, 2, Rock 7003, Wailau, Molokai; 3, Faurie 374; 4, Fosberg 13451, Wailau, Molokai; 5, Forbes 237-M; 6, Skottsberg 800; 7, Degener and Nitta 9430, sheet 2. (All in Bishop Mus.) All natural size.

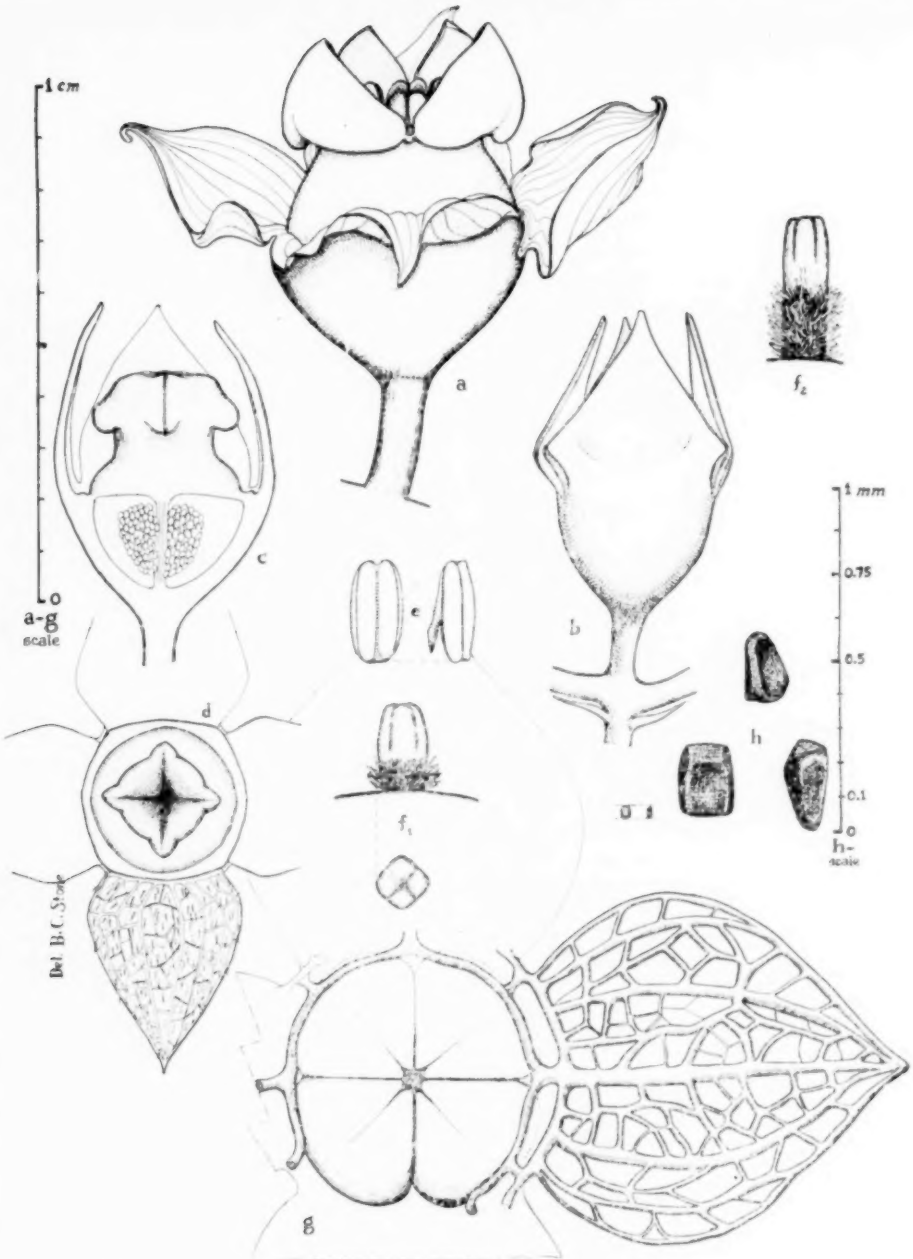

FIG. 2. *Hedyotis St.-Johnii*. a, Young flower; b, bud showing calyx; c, cross-section of bud, showing young corolla; d, top view of bud with calyx lobes spread; e, anther, front and side; f_1, young pistil; f_2, older pistil; g, fruit, top view, showing calyx expansion and dehiscence lines; h, seeds. All × 7½.

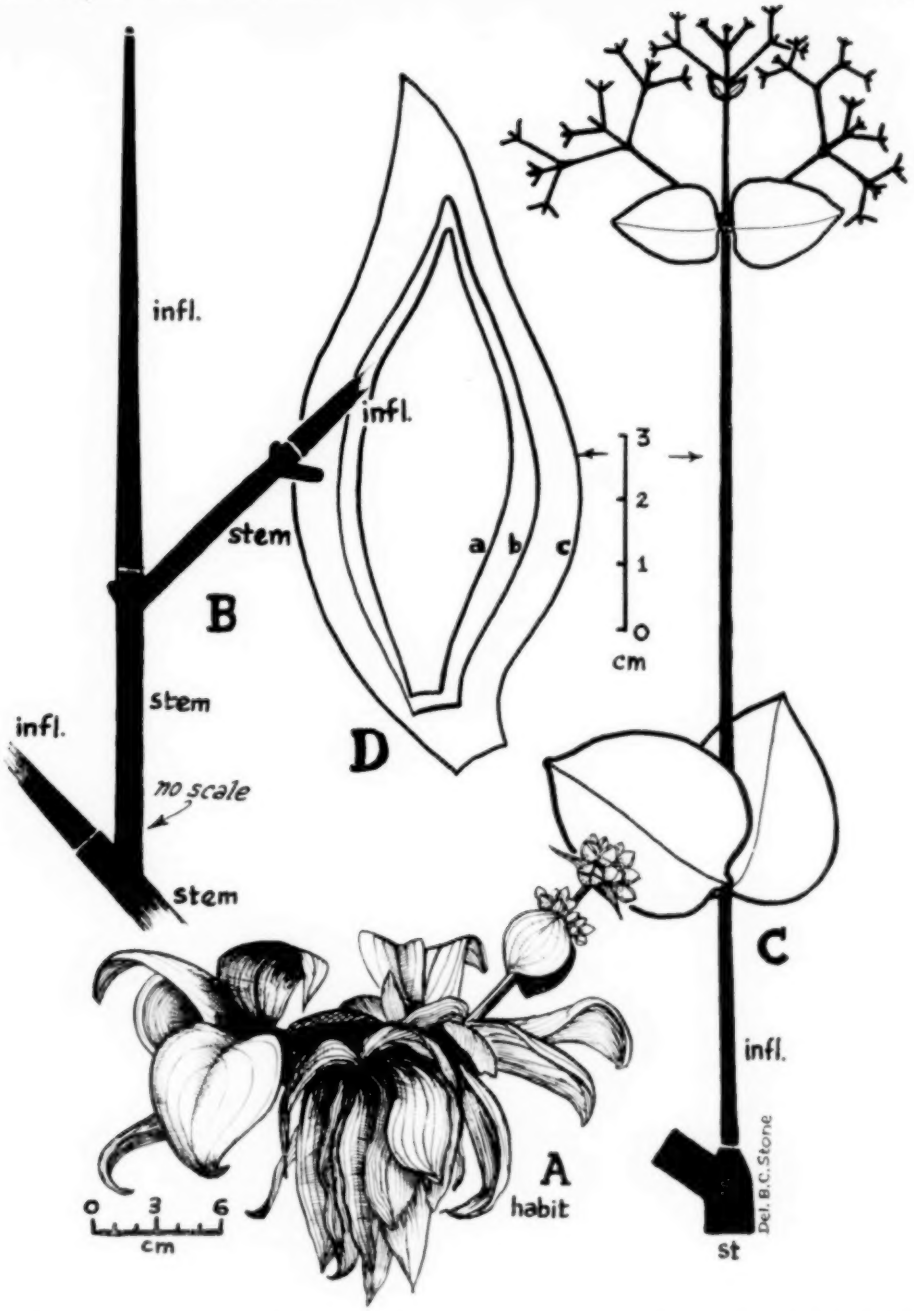

FIG. 3. A, *Hedyotis St.-Johnii*, habit sketch, (from Kodachrome by B. C. Stone); B, stem, branching pattern, showing terminal inflorescences; C, inflorescence; D, representative leaves. A- × ½; B-D, × 1.

11 floris ferrens, flos omnis bracteolo unico subulato fere 1 mm. longo subtentus, bracteae 2 rare 4–6 ovatae vel subcordatae ad apicem acutae vel subacuminatae 1–3 cm. longae 1.3–2.1 cm. latae inferiores longiores, flos junior subcuboideus, flos vetustior urceolatus 8–11 mm. diam., pedicellus 2 mm. longus, calyx in alabastro valvatus 4-lobatus, lobi calycis hastati subrhomboidali 4–6 mm. longi quam corollam longiori, corolla in alabastro ad apicem depressa 5–8 mm. longa lobi in flore leviter divergentes 1.5–2.5 mm. longi viridi, stamina subsessilia cum corolla adnata vix exserta, antherae 1.5 mm. × 0.8 mm., pistil 1, ovarium inferius, hypanthio discoideo, stylus ca. 3 mm. longus in basi pubescenti ad apicem quadrifidem, fructus siccus lentiformis vel subglobosus calyx persistens accrescens ad mediam fructus cinctus, fructus 4-locularis dehiscens primo loculicidalis illo tempore septicidalis, maturitas 4–6 mm. diam., semina angulosa nigra 0.2 mm. longa.

Ab. *H. littoralio* corolla brevioribus urceolati viridi (non albi) et fructu lentiformi differt.

Suffrutescent, decumbent, sparsely branching plants growing on rocky cliffs near the sea (known only from near Kalalau, Kauai), with woody stems up to 30 cm. long covered by a corky, longitudinally grooved epidermis and banded by corky rings and the connate bases of the petioles, the stems usually hidden by the congested persistent opposite dead and living leaves, the branching pattern subscorpioid and the branches somewhat parallel, inflorescences terminating each branch and a new branch growing from the axillary bud just below the inflorescence (or sometimes both buds developing into branches), these branches in turn terminating in inflorescences, etc. The stems may reach a diameter of 1–2 cm. at the base, and are light brown to whitish in color. Leaves simple, entire, elliptical-acuminate with assymmetric curved apices, the length-width ratio rather variable, the petioles broad or alate and conspicuously connate, the blades 5–14 cm. long and 2–5.5 cm. wide, the surfaces minutely white-scabrous, the leaves when living rather fleshy, convex, dark shining green above and rather glaucous, but with darker veins, below; veins barely prominent, the 4–10 lateral nerves curving parallel, hardly anastomosing; the veinreticulae apparent but delicate. Inflorescence terminal but seemingly axillary because of subscorpioid branching, the inflorescence up to 17 cm. long, a thyrsoid compound tripartite cyme, with each branch a strict dichasium of about 11 flowers, each flower subtended by a bracteole 1 mm. long, subulate in form; the dichasial branches average 1.5 cm. in length; the entire cluster of flowers may reach 2–3 cm. in width. Flowers in bud subcuboid, at anthesis urceolate, when mature 8–11 mm. in diameter; calyx glaucous green, glabrous except for minute white scabrae, in bud valvate, subcuboid, with four hastate subrhomboidal lobes whose basal corners are recurved-approximate, free; calyx longer than the corolla; the calyx-lobes in bud ca. 2 mm. long, in flower ca. 3 mm. long, in fruit ca. 8–10 mm. long; corolla green, in bud valvate, the four lobes inflexed at the top of the bud and forming a depression; in flower spreading or barely ascending, darker green within; corolla in bud 2–3 mm. long, in flower 5–8 mm. long, the lobes 1.5–2.5 mm. long, subtriangular, the neck constricted, the outer edges of the petals somewhat recurved or appearing ridged. Stamens 4, subsessile, adnate to the constricted neck of the corolla, the tips barely exserted, anthers 1.5 × 0.8 mm., the connective-filament 0.1–0.2 mm. long, anther-cells 4. Pistil 1, the ovary inferior, the hypanthium discoid, in flower not squared but becoming slightly so in fruit, 3–4 mm. wide in flower; style deeply quadrifid, the 4 lobes cohering; basal part of the style pubescent; lobes of the style 0.4 × 0.15 mm. Fruits dry, flattened-lentiform to depressed-subglobose, the calyx-lobes persisting-accrescent to about twice the size they are in flower, lobes fenestrate, 5–7+nerved, spreading, attached at the equator of the fruit; fruit

dehiscing first loculicidally across the disc, the pyrenes later separating by a septicidal slit. Seeds angular, blackish, papillose to granulate, small, ca. 0.2 mm. long.

HOLOTYPE: Hawaiian Islands, Kauai: Between Kalalau and Honopu, cliffs at end of beach; plants growing on rocky ledges and in crevices dashed by ocean spray, 10–30 ft. elevation, in association with *Artemisia australis* and *Lipochaeta succulenta*, December 24, 1956, Benjamin C. Stone no. 1470 (2 sheets, in Bishop Museum). (This locality is actually the same as the following.)

SPECIMENS EXAMINED: Hawaiian Islands, Kauai: Third gulch from east end of Honopu (Kalalau Trail), rare, in crevices of vertical basalt sea cliff, 10 ft. alt., herbaceous, leaves fleshy, above dark shiny green, below pale green with darker veins; infl. green, the buds cuboid, the calyx lobes valvate, within pale green, the corolla lobes valvate, within dark green, without pale green, assurgent; anthers exserted, yellow; December 31, 1947, Harold St. John, E. J. Britten, and R. S. Cowan no. 23,207 (2 sheets, in Bishop Museum).

DISCUSSION

Because of the close vegetative similarity of the species *Hedyotis littoralis* (Hillebrand) Fosberg and the newly described *H. St.-Johnii* Stone and Lane, there is the possibility that Hillebrand's collection from Hanalei, Kauai, might represent *H. St.-Johnii* rather than *H. littoralis*. Hillebrand (1888) added after the description of his *H. littoralis*, "On rocks near the seashore in Waikolu, Molokai! and Hanalei, Kauai! A single damaged corolla only was available for examination; the position of the anthers, shape of corolla lobes, and relative length of style remain therefore doubtful." Possibly also the color of the corolla in the Hanalei specimen was unknown. At any rate, until new and definite collections of *H. littoralis* are made on Kauai, it must remain a matter of doubt whether both of these species are actually present there. Since, however, the only two collections of *H. St.-Johnii* are from nearly the same locality along the Napali coast (Honopu and Kalalau are only about 3 miles apart, as the crow flies), and Hillebrand's specimen was from Hanalei, perhaps 15 miles away and in a less rugged and rocky area, the possibility still exists that this latter specimen represents *H. littoralis*.

Hedyotis St.-Johnii was first collected in 1947, by St. John, Britten, and Cowan, and was rediscovered in 1956, during a trip into the isolated and remote Kalalau Valley led by Harold St. John. About 10 plants were seen, at various heights from 10 to 30 feet up, on the vertical basalt faces of the cliffs at the west end of the beach between Kalalau Valley and Honopu Valley. Flowers and fruit seemed abundant, and the colony though small seemed healthy. The plants were continuously sprayed by a fine spume from the breaking waves. The only plant associates were *Artemisia australis* Less. and *Lipochaeta succulenta* DC., though other species were growing nearby at the base of the cliffs back of the beach.

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Harold St. John, Senior Professor of Botany at the University of Hawaii, in whose honor this new species is named, for his generous assistance in the preparation of this paper, and for the opportunity and inspiration to study the Hawaiian flora; and to Mrs. Nancy Higgins, without whose ingenuity the second collection might never have been made.

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FOSBERG, F. RAYMOND. 1943. The Polynesian species of *Hedyotis* (Rubiaceae). *Bernice P. Bishop Mus., Bul.* 174: 1–101.

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Revisionary Notes on the Phoxocephalidae (Amphipoda), with a Key to the Genera[1]

J. Laurens Barnard[2]

Nomenclatural changes deemed necessary by the writer are briefly discussed herein, including: (1) a new synonymy for the genus *Paraphoxus* Sars and a listing of useful specific criteria for that genus; (2) new combinations and new names in the genera *Paraphoxus*, *Heterophoxus* Shoemaker, and *Proharpinia* Schellenberg; (3) zoogeographical reasons for the provisional retention of the genus *Harpiniopsis* Stephensen; and (4) a new key to the existing genera of the Phoxocephalidae.

Initially, this study was a local faunistic problem in the marine basins off southern California (Hartman, 1955; J. L. Barnard, 1955). The wealth of materials collected in several hundred bottom samples by the research vessel, "Velero IV," necessitated an extensive review of phoxocephalid systematics in order to assign the many new species to appropriate genera. The present paper is confined only to a rearrangement of names and synonymies in the literature.

The writer wishes to acknowledge the help of the following persons for the loan of specimens and for advice: Dr. Olga Hartman, Hancock Foundation; Dr. Keith Sheard, C. S. I. R. O. Division of Fisheries, Western Australia, who examined Haswell's types for the writer through the courtesy of Dr. J. W. Evans, director, The Australian Museum, Sydney; Dr. D. E. Hurley, New Zealand Oceanographic Institute; Dr. T. Soot-Ryen, director, Tromsø Museum; Dr. Karl Lang, Swedish State Museum of Natural History; Dr. Fenner A. Chace, Jr., and Dr. Thomas E. Bowman, U. S. National Museum; and Prof. E. Percival, Canterbury University College, Christchurch, New Zealand.

Paraphoxus Sars, new synonymy

Paraphoxus Sars, 1893: 148.
Pontharpinia Stebbing, 1897: 32.
Parharpinia Stebbing, 1899: 207.
Protophoxus K. H. Barnard, 1930: 335.
Trichophoxus K. H. Barnard, 1930: 336.
Metharpinia Schellenberg, 1931: 65.

Examination of specimens of *Paraphoxus oculatus* Sars from Norway, the type species of the genus, revealed a biarticulate first maxillary palp and not a uniarticulate condition as shown by Sars in 1893. Historically, the other genera in the above synonymy have been separated from *Paraphoxus* by the possession of a biarticulate palp; therefore, this distinction is no longer valid.

The genera *Parharpinia* and *Protophoxus* were already fused to *Pontharpinia* by Pirlot (1932). The genus *Trichophoxus* was based on the elongated fifth articles of the gnathopods, but the writer has found that this is not unusual in paraphoxids and of no generic value. *Metharpinia* was founded on species bearing narrowed rostrums (also characteristic of

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Trichophoxus) but the writer has found species which intergrade between the broad and narrow rostral types. However, it is useful to separate the two groups as subgenera, using the names *Paraphoxus* s.s. (broad rostrums) and *Trichophoxus* (narrow rostrums).

SPECIFIC CRITERIA IN THE GENUS PARAPHOXUS

Much of the apparent confusion in phoxocephalid systematics stems from the superficial lack of specific criteria. It is often the case that two species may appear quite similar with respect to head, gnathopods, peraeopods, uropods, and third epimera, which are the characters most useful systematically in other amphipods. Additional specific differences have been sought and one of the most important of these is the condition of the epistome. The presence of an acutely produced epistome in one of a pair of otherwise similar species has been most useful in calling attention to their distinctness and to a need for statistical measurement of other minor differences. *Pontharpinia epistoma* Shoemaker, 1938, was the first phoxocephalid described with a produced epistome. In the materials at hand are nine other new species bearing produced epistomes of varying extent, several of which are otherwise scarcely distinguishable from relatives in which the epistome lacks an anterior process.

Unfortunately, many of the existing specific descriptions of paraphoxids are practically useless and all species should be re-examined according to the following list of criteria. Due to the fact that seemingly minute differences may have specific value, drawings are far more useful than words.

The criteria deemed important by the writer and for which figures should be drawn are:

1. Dorsal shape of head and rostrum.
2. Size of eyes in both sexes in relation to size of head.
3. Shape of epistome from lateral view.
4. Presence or absence of a distal spine or claw on palp article 4 of the maxilliped.
5. Shape and size of articles 5 and 6 in both pairs of gnathopods.
6. Stoutness of spination on article 5 of peraeopods 1 and 2.
7. Unusual features of the coxae.
8. Ornamentation and proportions of the articles of peraeopods 3, 4, and 5.
9. Configuration and armature of pleonal epimera 2 and 3.
10. Spination of uropods 1 and 2.
11. Proportions of uropod 3. The length of the inner ramus on the female is quite variable interspecifically, as is the length and shape of article 2 of the outer ramus.
12. Breadth, apical shape, and armature of telson.
13. Breadth and dorsal depression of body.

Paraphoxus milleri (Thorsteinson), new combination, new synonymy

Pontharpinia milleri Thorsteinson, 1941: 82.
Pontharpinia longirostris Gurjanova, 1938: 263 (=Homonym, not Schellenberg, 1931).
Pontharpinia robusta Gurjanova, 1938: 262 (=Homonym, not Holmes, 1908).

A study of the variability of this species in eastern Pacific waters indicates that the names above should be fused. Both of the earlier names of Gurjanova are junior homonyms so that the only available name is *P. milleri*.

Paraphoxus obtusidens (Alderman), new combination, new synonymy

Pontharpinia obtusidens Alderman, 1936: 54.
Pararpinia (*sic*) *pontarpioides* Gurjanova, 1953: 229.

The description and figures of the junior synonym represent one form of this variable northern Pacific species.

Paraphoxus sinuatus (K. H. Barnard), new combination, new synonymy

Parharpinia villosa, Schellenberg, 1931: 75 (not Haswell, 1879).
Parharpinia sinuata K. H. Barnard, 1932: 103–104, fig. 52.

The examination of the type of *P. villosa*, from Australia, by Dr. Keith Sheard and of Schellenberg's material, from South America, by the writer revealed several important differences in the South American species. The *Parharpinia villosa* of Schellenberg differs from the holotype by: (1) article 5 of gnathopod 1 shorter than 6, as opposed to longer than 6 in *P. villosa;* (2) article 6 of gnathopod 1 with parallel margins, as opposed to rounded in *P. villosa;* (3) article 4 of peraeopod 3 is only two thirds as wide as article 2 while it is fully as wide as article 2 in *P. villosa;* (4) article 2 of peraeopod 5 has the posterior edge with sparse and poorly setose serrations while in *P. villosa* it has numerous fine crenulations with long setae; (5) the peduncle of uropod 1 has numerous spines of strikingly different sizes on the inner and outer margins, as opposed to sparse similar spines on both margins in *P. villosa;* (6) the inner ramus of uropod 2 bears spines but lacks them in *P. villosa*.

Statistical analysis of large collections may show these differences to be of subspecific value only; in any case the South American specimens need nomenclatural segregation. This is provided by K. H. Barnard's name, *P. sinuata*, which by its description, figures, size, and geographic location is shown to be conspecific with Schellenberg's material.

Paraphoxus tattersalli, new species

Pontharpinia villosa, Tattersall, 1922: 4 (not Haswell, 1879*a*).

The clear figures published by Tattersall show striking divergence from the type of *P. villosa* which was examined by Dr. Sheard. Some of the many differences of *P. tattersalli* are: (1) gnathopods 1 and 2 differ in size greatly, while in *P. villosa* they are similar in size; (2) the short fifth articles of the gnathopods; (3) the very narrow plate of article 2 of peraeopod 5 compared with the very broad one in *P. villosa;* (4) article 4 of peraeopod 3 is half as wide as article 2, while in *P. villosa* it is fully as wide as article 2.

Paraphoxus stebbingi, new species

Pontharpinia pinguis, Stebbing, 1897: 33; Stebbing, 1906: 146 (in part); Stebbing, 1910: 635 (in part) (not Haswell, 1879*b*).

Stebbing's clear description and figures reveal several differences from the type of *P. pinguis* (Haswell), which was examined for the writer by Dr. Sheard. *Paraphoxus stebbingi* differs from *P. pinguis* by: (1) a minute cusp on the posteroventral corner of the third pleonal epimera, as opposed to a long, upturned cusp in *P. pinguis*, overlooked by Haswell in his description of the species; (2) the very elongated fifth articles of the gnathopods; (3) the narrow sixth articles of the gnathopods as opposed to the broad articles in Haswell's original drawing of *P. pinguis* (the sixth articles are missing on the type specimen of *P. pinguis*).

Heterophoxus oculatus (Holmes), new combination, new synonymy

Harpinia oculata Holmes, 1908: 521.
Harpinia affinis Holmes, 1908: 523.
Heterophoxus pennatus Shoemaker, 1925: 22.

The types of *H. oculata* and *H. affinis* in the U. S. National Museum were examined and found to be conspecific with *H. pennatus*. The name *oculatus* was chosen from Holmes' names on the bases of page priority, the better condition of the holotype, and the appropriateness of the name, referring to an animal with eyes.

Heterophoxus ophthalmicus (Schellenberg), new combination

Harpinia ophthalmica Schellenberg, 1925: 136.

Schellenberg's description is that of an heterophoxid, as shown by the presence of eyes, the ensiform process on the second antenna and the short fourth maxillipedal palp article bearing a long seta. However, on the basis of the description, the species cannot be differentiated from others in the genus *Heterophoxus*.

Proharpinia stephenseni (Schellenberg), new combination

Heterophoxus stephenseni Schellenberg, 1931: 73.

The type species of *Proharpinia* is *P. antipoda* Schellenberg, (1931: 80). Specimens of both *P. antipoda* and *H. stephenseni* were compared and found to be congeneric. The genus *Proharpinia* differs from the genus *Heterophoxus* only by: (1) the lack of an ensiform process on antenna 2; (2) the presence of a cusp on the lower anterior corner of the head. *Proharpinia stephenseni* may be separated from *P. antipoda* by: (1) the lack of teeth on article 2 of peraeopod 5; (2) a shorter tooth on the third pleonal epimera.

Proharpinia hurleyi, new species

Harpinia obtusifrons, Chilton, 1909: 619 (in part) (not Stebbing, 1888); Stephensen, 1927: 306 (not Stebbing, 1888).

Heterophoxus stephenseni, Hurley, 1954: 589 (not Schellenberg, 1931).

Some of Schellenberg's original material of *H. stephenseni* from South America (see previous species) and Hurley's specimens from New Zealand were compared and both were found to belong to the genus *Proharpinia*. However, the New Zealand specimens are a distinct species and differ from the *P. stephenseni* of South America by: (1) the presence of minute serrations on the posterior edge of peraeopod 5, article 2; (2) the longer tooth on the third pleonal epimera; (3) the stouter, longer spines on the telsonic apices; (4) the longer rostrum, smaller eyes of the female, and the smaller process on the lower anterior corner of the head; (5) the relatively longer sixth articles and more oblique palms of the gnathopods.

Chilton's specimens reported in 1909 (deposited at Canterbury University College) were examined and some were found to be *P. hurleyi* while the rest could not be identified. The reference of Stephensen (1927) was originally included as a part of the synonymy of *Heterophoxus stephenseni* by Schellenberg (1931) but it is clear from Stephensen's figures that the material belongs with *P. hurleyi*.

A ZOOGEOGRAPHIC NEED FOR THE PROVISIONAL USE OF THE NAME HARPINIOPSIS

The type species, *Harpiniopsis similis*,of this monotypic North Atlantic genus, described by Stephensen (1925) was submerged in the genus *Harpinia* by Gurjanova (1951).

The genus *Harpiniopsis* differs from *Harpinia* Boeck mainly by the very elongated male second antennae, a criterion generally true of all phoxocephalids, except for the specialized Harpinias. Although the writer deplores the use of secondary sexual criteria on which to base genera, he favors the retention of the name *Harpiniopsis* to designate a special group of harpiniids which may have important zoogeographic meaning.

The presence of only one species of *Harpiniopsis* in the rather well-explored northeastern Atlantic, compared with at least five undescribed species discovered by the writer in the eastern Pacific Ocean, is one example of the sparse representation of certain phoxocephalid genera in European Atlantic faunas. Another example of this is the presence of only one species of *Paraphoxus* in the northeastern Atlantic compared with several dozen species in the Pacific Ocean. On the other hand, the specialized genus *Harpinia*, which may have a *Harpiniopsis*-like ancestor, has many species in the European Atlantic but none in the tropical and temperate Pacific.

These facts lead to the suggestion that the Pacific Ocean, which is abundantly supplied with basic types of phoxocephalids such as *Paraphoxus* and *Harpiniopsis*, was the evolutionary center for the group. The only species of *Paraphoxus* in the northeastern Atlantic is also present in the northern Pacific, suggesting that it was the only one which successfully migrated to or survived in that part of the Atlantic. Only one species of *Harpiniopsis* survived in the north Atlantic, while its more specialized relative, *Harpinia*, probably

evolved in and dominated the northeastern Atlantic phoxocephalid fauna. In light of the cold water habitats of the species of the genera in question, the migration pathway for these events undoubtedly occurred north of the American or Asian continents.

In the western Atlantic Ocean, along the warmer eastern shores of the Americas, is a *Paraphoxus* fauna closely allied and in some cases identical specifically with that in the tropical and semitropical eastern Pacific Ocean. It is of considerable interest that none of these paraphoxids has appeared in the warmer eastern Atlantic, suggesting difficulty or slowness of migration, or the inability to compete in the harpiniid-dominated eastern Atlantic.

Although these facts are meager they nevertheless point to a pressure of migration from the generalized and mixed phoxocephalid faunas of the northeastern Pacific Ocean to the more specialized, sparser, and geographically isolated faunas of the Atlantic Ocean.

It is advisable to retain the name *Harpiniopsis* for a group of species which are closely related to a theoretical precursor of the genus *Harpinia* and which, through distributional studies, may shed further light on the relationships of Pacific and Atlantic faunas.

KEY TO THE EXISTING GENERA OF PHOXOCEPHALIDAE[3]

1. Peraeopod 3, article 2 more than twice as wide as article 3 2
1. Peraeopod 3, article 2 about as wide as article 3 6
2. Maxilla 1, palp biarticulate 3
2. Maxilla 1, palp uniarticulate 4
3. Antenna 2, flagellum multiarticulate, gnathopods 1, 2 similar in size . **Paraphoxus**
3. Antenna 2, flagellum biarticulate, gnathopod 1 much larger than 2 . . . **Joubinella**
4. Mandible, molar bearing ridges and cusps . . . . . **Phoxocephalus**
4. Mandible, molar smooth or with a few spines 5
5. Eyes present, maxillipedal palp article 3 unproduced . . . . . **Metaphoxus**
5. Eyes absent, maxillipedal palp article 3 produced conically . . . . . **Leptophoxus**
6. Eyes absent 7
6. Eyes present 9
7. Head with dorsal crest, uropod 2 with apical ramal spines . . . . . **Pseudharpinia**
7. Head lacks dorsal crest, uropod 2 lacks apical ramal spines 8
8. Antenna 2 in male very short . . . . . **Harpinia**
8. Antenna 2 in male as long as body . . . . . **Harpiniopsis**
9. Antenna 2 with basal ensiform process . . . . . **Heterophoxus**
9. Antenna 2 lacks basal ensiform process . . . . . **Proharpinia**

[3] The genus *Phoxocephalopsis* Schellenberg, 1931, was placed in the family Haustoriidae by K. H. Barnard, 1932, although it is intermediate between that family and the Phoxocephalidae.

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Studies on Luminescence in Marine Snails

Y. HANEDA[1]

AMONG THE GASTROPODA Opisthobranchiata certain genera of the Polyceridae, Tethyidae, and Phillirhoidae are luminous. Among the Gastropoda Pulmonata two luminous species are known: *Latia neritoides*, fresh water limpets, first discovered in New Zealand by Suter (1890), and *Dyakia striata*, land snails, found by myself in Singapore in 1946.

Luminous species of Gastropoda Prosobranchiata are very rare, however, according to E. N. Harvey in his book *Bioluminescence* (1952). Turner in 1948 informed him by letter that *Tonna galea* Linné, a marine snail, is luminescent. When this snail moves through water with its foot well extended, it emits a greenish-white light. A species of doubtful luminescence is also found among the heteropods (Pterotracheata) according to Keferstein in Bronn's *Tierreich* (1862–1866).

We have found two species of luminous marine snails on Borawazawa Beach, at Suyeyoshi Village, which is located on Hachijo Island, 157 miles south of Tokyo. This discovery was made during ebb tide on April 23, 1953. While I was strolling on the beach with an acquaintance, Mr. H. Okuyama, teacher of Suyeyoshi Primary School, he chanced to raise a stone, and we were both astonished to find under it some small marine snails which were emitting light as they rolled in the water. Excitedly we collected many specimens, examining them closely to find out if these marine snails were really luminous, or whether their luminescence was due only to their having eaten some luminous matter or to infection with luminous bacteria.

As a result of subsequent experiments, I decided that these snails were true luminous animals, possessing luminous organs on their mantles (Haneda, 1955).

During a trip to the Luminescence Conference at Pacific Grove, California, for the meeting of March 29–April 1, 1954, I had the opportunity to continue my studies of these interesting animals. I collected another species of luminous snails on Waikiki beach, Oahu, and one other species on Onekahakaha beach, Hawaii, and on the beach at Key West, Florida (see Haneda, 1955).

ACKNOWLEDGMENTS

To the following people I must express my sincere gratitude and appreciation: To Professor S. Hatai, chairman of the Committee on the Research of Marine Resources, sponsored by the Japanese National Commission for UNESCO, for having given me the opportunity to carry out this present work; to Professor E. Newton Harvey of Princeton University and Professor Bernard L. Strehler of the University of Chicago, both of whom gave me much instructive advice; to Dr. I. Taki of the National Science Museum in Tokyo, and to Mrs. Anna Harris of the Bernice P. Bishop Museum in Hawaii, both of whom identified the specimens of *Planaxis;*

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to Mr. Y. Shinoda and Mrs. S. Nunes, for their assistance in collecting materials during my stay in Hawaii; to Mr. H. B. Summers, for having assisted me in the preparation of the manuscript; and to Mr. H. Okuyama of Nakanogoh Primary School of Hachijo Island who assisted in collecting materials, and whose keen observations made this discovery of luminescence in *Planaxis* possible.

I would also like to express my warmest appreciation to the Committee of the Luminescence Conference, for inviting me to participate in the meetings of March 29–April 1, 1954 at Pacific Grove, California, which gave me the opportunity to collect many American specimens.

MATERIALS

The luminous marine snails which I have collected all belong to the genus *Planaxis* of the Planaxidae and are comparatively small. The various species of this genus in which I have observed luminescence are shown in Table 1.

All of these animals are capable of living in aquaria for a long time, usually up to two to three months, and in some cases as long as one year. I collected many specimens in April at Hachijo Island and brought them to my laboratory in a small bottle. These animals lived in a small dish until the end of August of the same year, during which period the water was changed several times. I twice air mailed several living specimens of *Planaxis virgatus* in a small bottle of sea water to Dr. E. N. Harvey of Princeton University. The first time all the specimens were dead when Dr. Harvey received them. But the second time the specimens arrived alive.

FIG. 1. *Planaxis virgatus.*

FIG. 2. *P. labiosus.*

I brought some specimens of the Hawaiian species in a small bottle of sea water to the Conference on Luminescence and demonstrated their luminosity to Dr. Harvey and other members present. Afterward I took those specimens on my journey in the United States and brought them back to my laboratory about two months later. The snails lived in a small aquarium until March 21, 1955, and some of them hatched larvae, but luminosity in these larvae was not observed.

OBSERVATION OF LUMINOUS PHENOMENA

Under natural conditions, the light of these animals cannot be seen well; they will emit light only under strong stimulation. If many specimens are placed in a bottle and are well shaken in the dark, some of them become luminous and twinkling. The light usually continues one or two minutes after stimulation, then gradually disappears. But if the body of the snails is irritated, the light re-

TABLE 1
DATE AND PLACE OF COLLECTION OF THE VARIOUS SPECIES OF THE GENUS *Planaxis* AND THEIR SIZE AND REMARKS

SPECIES	PLACE	DATE	SIZE OF SHELL		REMARKS
			Height, mm.	Diameter, mm.	
Planaxis virgatus Smith	Borawazawa Beach, Hachijo I., Japan	April, 1953	8.0	4.0	Luminous
	Habu, Ohshima I., Japan	Oct. 1953			
P. periscelida Dall	Heta, Izu Peninsula, Japan	May, 1953	3.5	2.0	Luminous
P. longispira Smith	Dogashima, Izu Peninsula Japan	Aug., 1953	6.0	2.8	Luminous
P. lineatus da Costa	Waikiki Beach, Honolulu, Hawaii	March, 1954	10.0	5.2	Luminous
P. labiosus A. Adams	Onekahakaha Beach, Hilo, Hawaii	March, 1954	10.0	5.0	Luminous
P. labiosus A. Adams	Key West, Florida	April, 1954			
P. sulcatus Born	Shirahama, Wakayama Pref., Japan	April, 1955	15.0	10.0	Non-luminous

appears once again. After crushing the shell and removing the body of the snail, a low power magnification will show that the luminous part of its body is situated on the mantle in a limited area (Fig. 3). When the body is put into fresh water, the light on the mantle continues as a more prolonged glow. However, after 10 or 15 minutes in fresh water, the animal becomes weak and its light cannot be seen even after strong stimulation. If the body is placed on photographic film for a few minutes in the dark, an image of the light appears.

Observed under the microscope in the dark, the luminous area of the snail takes on the appearance of a night sky. Minute luminous points glimmer and twinkle like so many stars. The luminescence of this animal is intracellular; no luminous slime goes into the surrounding sea water. Among the six species of Planaxidae, which were examined, the following five have the same type of luminous organ: *Planaxis virgatus*, *P. longispira*, *P. periscelida*, *P. lineatus*, and *P. labiosus*. *P. sulcatus*, however, has no luminous organ at all.

EFFECTS OF TEMPERATURE

No effects are noticable to the naked eye in the intensity of luminescence in marine snails under thermostimulation. Through the use of the highly sensitive 1921 photomultiplier, followed by two stages of amplification feeding into a Brown recorder, however, the light intensity changes resulting from changes in temperature are readily discernible. I had the opportunity to make use of such equipment through the kind offices of Dr. Bernard L. Strehler of the Department of Radiobiology at the University of Chicago when I visited that institution in April, 1954. Our tests were extremely interesting. Contained in a small glass tube of sea water at a temperature of 15° C., the snails were placed near the photomultiplier and the temperature of the tube was raised and lowered in two successive cycles and the light intensity recorded.

From an initial centigrade reading of 15° C. the snails' temperature was raised to 45° C. and lowered to −10° C. in a period of less than 10 minutes. From this point the temperature was again raised gradually to 60° C. and lowered to 15° C. During the first cycle the maximum of relative light intensity was at 45° C. As the temperature decreased so did the intensity, until at −10° C. it could not be detected.

During the second cycle, however, the in-

tensity became progressively weaker after 30° C., despite an increase of temperature to 60° C. At this point the intensity had dropped to zero, and during the following decrease in temperature, it showed no discernible recovery. As far as could be determined, the snails had died at approximately 60° C.

STRUCTURE OF THE LUMINOUS ORGAN IN *Planaxis labiosus*

The luminous organ, situated on the dorsal part of the mantle in the limited area shown in Figure 3, is a translucent pale blue color when fresh. The external visible area of this luminous organ consists of many folds of luminous tissues which run parallel with each other. If the body is taken out of the shell and put into an aluminum morine solution (diluted 500,000 times) for a few minutes and then washed carefully in fresh water, it is possible, by observation with Yasaki's fluorescent microscope (1952), to see the beautiful blue-green fluorescent light which these luminous tissues emit. The structure of all five luminous species of *Planaxis* is practically the same: the luminous cells are restricted to this area of the mantle.

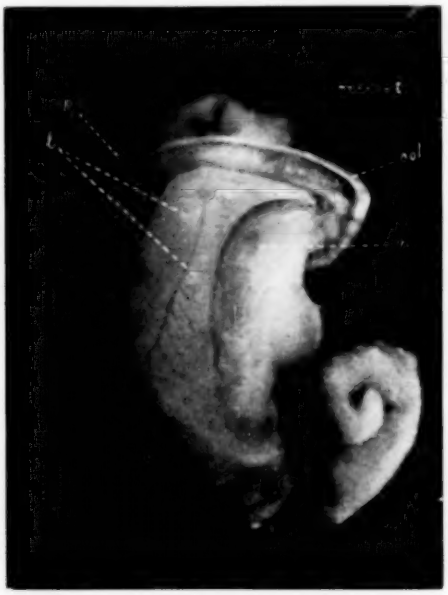

FIG. 3. Dorsal view of the body of *Planaxis labiosus*, removed from the shell. *l*, Luminous area of mantle; *m*, mantle; *col*, collar; *p*, propodium; *t*, tentacles.

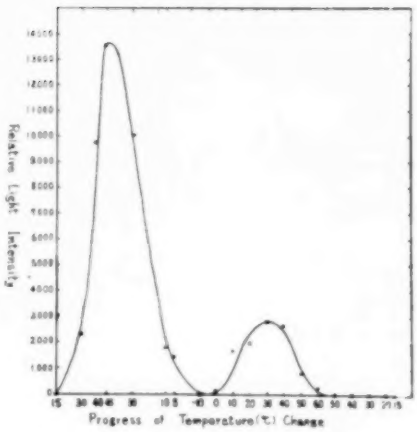

FIG. 4. Effect of temperature on *Planaxis labiosus* luminescence. (Numbers on the vertical axis are counts of the recorder of the photomultiplier.)

HISTOLOGY

Since the luminescence of this snail is localized in a limited area on the mantle and the animal is small in size, the whole body was preserved in a fixative of sea water prepared with formalin and Bouin's solution. The material was cut in 10 μ sections both longitudinally and transversely. The stains used were haematoxylineosin and aluminum morine. The appearance of the longitudinal section of the mantle is much like that of a comb. On the inside of the mantle, where the luminous area is situated, there appeared many pleats arranged in parallel, but it was impossible to determine whether or not these pleats contain luminous cells. However in the luminous area of the mantle, under the thin epithelium, there appeared many cellular masses, which very probably contain the photogenic tissues of this body. Each of these masses consists of small, closely packed cells.

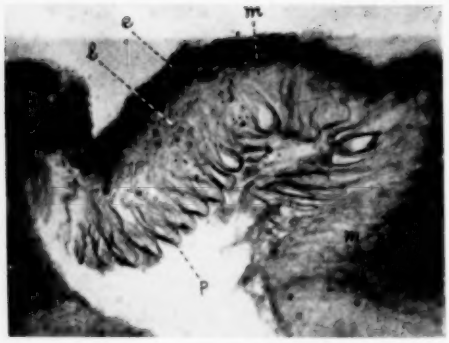

FIG. 5. Longitudinal section of the mantle containing luminous tissue of *Planaxis labiosus*. *l*, Luminous tissue; *m*, mantle; *p*, pleats; *e*, epithelium.

The character of these cells indicates that the luminescence must be intracellular.

BIOCHEMISTRY

Further experiments to relate luminescence to biochemistry were carried out as follows. A number of the snails were removed from their shells and thoroughly dried. They were then ground in a mortar and moistened with water, but luminescence did not appear. A negative luciferin-luciferase reaction was obtained by mixing hot water and cold water extracts of the crushed bodies. If the cold water extract of crushed luminous snails is allowed to stand until the luminescence of the extract disappears, it will not recover its luminescence even when ATP (Adenosinetriphosphate) is added.

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Contributions to the Knowledge of the Alpheid Shrimp of the Pacific Ocean
Part III. On a Small Collection from Onotoa, Gilbert Islands[1]

ALBERT H. BANNER[2]

THIS PAPER reports on a small collection of snapping shrimp made at Onotoa in the southern Gilbert Islands during the summer of 1951 by the members of the Coral Atoll Research team during the investigation of the total ecology of the atoll under the sponsorship of the Pacific Science Board with funds from the Office of Naval Research (Contract NR 160–165). Members of the team working on the ecology of marine animals were Dr. Preston E. Cloud, Jr. of the U. S. Geological Service, Dr. Donald W. Strasburg, Dr. John E. Randall, and myself. The latter three at the time were with the University of Hawaii.

The study of these shrimp was initiated under a grant administered by the U. S. National Museum and the Pacific Science Board under a contract between the Office of Naval Research, Biology Branch, and the National Academy of Sciences (NR 160–175); some help in the final phases of the study was gained through a grant from the National Science Foundation (NSF-G-1754). I also wish to acknowledge the aid that was given me in the field by Drs. Cloud, Strasburg, and Randall.

In order to save space and time in this paper, as in the second study, instead of giving complete synonymy and bibliographic references for each species, reference will be made to the earlier papers of the series whenever a species has been listed before.

Type specimens of the new species described in this paper will be deposited in the institution from which they were borrowed; those types in my personal collection will be deposited either in the U. S. National Museum or the Bernice P. Bishop Museum.

ONOTOA ATOLL

Onotoa is a small, relatively dry atoll in the southern portion of the Gilbert Islands. This portion is known also as the Kingsmill Islands. It lies at 1°47′ S., 175°29′ E. (north anchorage) and is slightly less than 12 miles long and 5 miles broad, while the land area, reaching along the eastern side of the lagoon, is only slightly more than half a mile wide at the broadest spot (Fig. 1). The windward or eastern side of the atoll has a broad reef flat varying from less than 1,000 to more than 2,000 feet in width; the outer edge of this flat is marked by a shallow trough, then a higher coralline ridge which breaks up into a series of well-developed surge channels; beyond the end of the surge channels is a narrow sloping shelf from 10 to 40 feet deep which drops off abruptly into deep oceanic water. The lagoon is shallow with the deepest measured point about 50 feet, while most of the lagoon area is less than 12 feet deep; large areas near the islands were exposed by low tides. The western edge of the lagoon was marked by an interrupted series of coral reefs growing to near the surface with shallow passes between them. The western edge of the atoll drops off into deep water almost as abruptly as does the eastern except off the northern anchorage to the west of the chief village. (Dr. Cloud has an extensive report on the physical and biological condition of the atoll in his 1952 report.)

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COLLECTIONS AND HABITATS

Unfortunately the collections from Onotoa are not very extensive. An infected leg prevented me from collecting for about half of the 10 weeks we spent on the island, and in the short time remaining I had to devote full time to making the ecological survey, collecting snapping shrimps only as they appeared in the transects. Most of this small collection was lost in transit from Onotoa via Kwajelein to Hawaii and, eventually, only a small proportion of the shrimp collected at Onotoa arrived in Honolulu. Most of the specimens available for study were those collected by Dr. Cloud incidental to his studies on marine geology. However, small as the collection is, it is important for there have been no previous records from the Gilbert Islands.

On the windward reef a transect 20 feet wide was taken normal to the beach line and reaching to the coralline ridge, 750 feet to seaward. Because of the great diversity of habitats and the limitations of time no extensive transects were taken on the lagoon side, but the different shallow water habitats were sampled individually (see Banner and Randall, 1952).

The ecological notes on the stations from which shrimp were examined (it should be noted that alpheids were collected at almost all stations) are as follows:

A-1. Starting with division between beach rock and higher sand beach, at about 2.4-foot tide zone, reaching seaward 50 feet; substrate of consolidated reef limestone; many tide pools, the largest up to 20 feet long, 5 feet wide, and 6 inches deep; both exposed areas and bottoms of tide pools with scattered loose rocks up to a foot square and 6 inches thick.

A-2. 50–100 feet from beach line, about 2.2-foot tide zone; similar in nature to A-1, but with fewer and smaller tide pools.

A-3. 100–150 feet from beach line, about 2.0-foot tide zone; substrate similar to A-1, A-2.

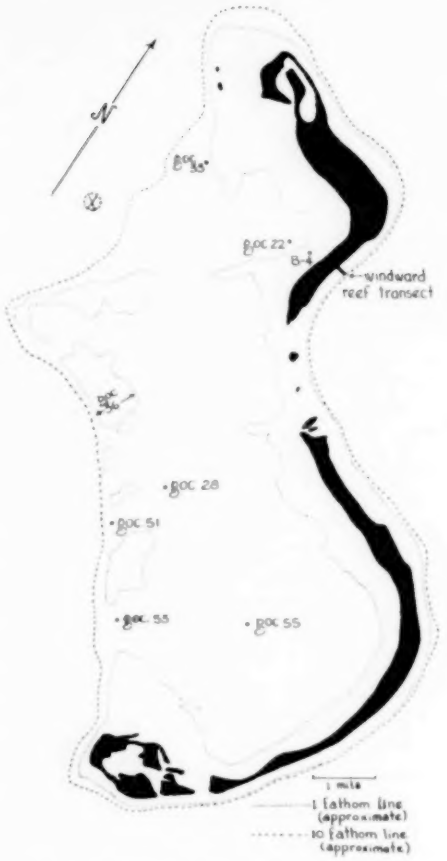

FIG. 1. Onotoa, Gilbert Islands, showing localities of collections. Place indicated by X is approximately 1°47′ S., 175°29′ E.

A-6. 250–300 feet from beach line, about 1.4-foot tide zone; about 30 per cent of area covered by very shallow tide pools. Substrate changing to a coralline algal sheet overgrowing dead coral heads *in situ* with numerous small holes passing through sheet into cavities remaining between the coral heads.

A-7. 300–350 feet from beach line, about 1.2-foot tide zone; about 80 per cent of the area covered by 1-inch-deep tide pools that only drain on extreme low waters; substrate as in A-6, but carpeted by thick tufts of green

algae in which many animals live; some loose rocks, several feet across, under which most of the snapping shrimp were collected.

A-10–12. 450–600 feet from beach line, 0.8–0.4-foot tide zone; about 70 per cent covered with shallow tide pools; substrate, algal covering, rocks similar to A-7; collecting of shrimp done at random in area wherever larger rocks occurred.

B-4. On sandy lagoon beach, about 0.0–2.0-foot tide level, 400 to 1,000 feet from high tide line; snapping shrimp collected from heads of dead coral protruding above the sand beach.

The following stations were those made by Dr. Cloud in which alpheids were collected:

GOC-22. Station nearly in line with B-4 above, 1,200 feet from shore, about 4–6 feet deep at low tide; substrate similar to B-4, but with more living and dead coral.

GOC-28. Middle lagoon region, from reef patches from 6 to 14 feet deep.

GOC-33. On outer edge of outer or western reef growth; depth from surface (low tide) to about 24 feet; flourishing coral growth.

GOC-36. Across surface of outer or western reefs; depth less than 6 feet; extensive coral growth separated by sandy areas.

GOC-51. In pass through western reef front; collections from coral patches, mostly of living coral, rising from sandy bottom at 15 feet to within 8–10 feet of surface.

GOC-53. A pass similar to GOC-51, bottom at 18 feet, coral patches rising to within 4 feet of surface.

GOC-55. From deepest spot on lagoon, sounded at 50 feet; bottom sandy to muddy, with scattered low clumps of living and dead coral.

SYNALPHEUS Bate

Synalpheus carinatus (de Man), 1888

For synonymy see Banner, 1957.

LOCALITY: 5 specimens from GOC-53.

DISCUSSION: These specimens, from the same collection that yielded the obviously closely related *S. consobrinus* de Man, have not been assigned to any of de Man's three subspecies. The subspecies were erected primarily upon the size of the ova, which were reported by de Man to be 0.4–0.5 mm. long in one subspecies, 0.9–1.0 mm. in the second, and 1.2 mm. long in the third. Of these specimens, three were ovigerous with the egg diameters 0.6 by 1.0 mm., 0.65 by 1.1 mm., and 0.65 by 1.5 mm. It was also noted that the smallest eggs had the youngest embryos, while the largest had embryos near hatching. The other characteristics used by de Man in the separation of the subpsecies are based on slight differences of variable characteristics, like the notch in the rostral carina, which in even these few specimens varied from well developed to almost nonexistent. Without other less variable characteristics to base the differentiation upon, with this group of specimens showing marked variation in the size of the ova, and with poecilogony well known among the synalpheids (see Coutière, 1899:444 *et seq.*) it appears that the division of the species into subspecies on these criteria is unrealistic.

Synalpheus amboinae (Zehntner)
Fig. 2

Alpheus amboinae Zehntner, Rev. Suisse de Zool. 2: 202, pl. 8, fig. 23 a, b, 1894.

Synalpheus amboinae de Man, Siboga Exped. 39a[1](2): 203, pl. 6, fig. 20, 1911.

LOCALITY: 3 specimens at GOC-53.

DISCUSSION: While these specimens are within the range of variation given by de Man (1911) and agree well with the descriptions of the species, they have been referred to this species with considerable doubts. They were collected at the same locality and at the same time as *S. consobrinus* de Man. These two nominal species differ in the presence of a tooth above the articulation of the large chela, and in slightly different proportions and armature of the telson. With the difference in the size of the specimens reported by de Man, one would suspect that

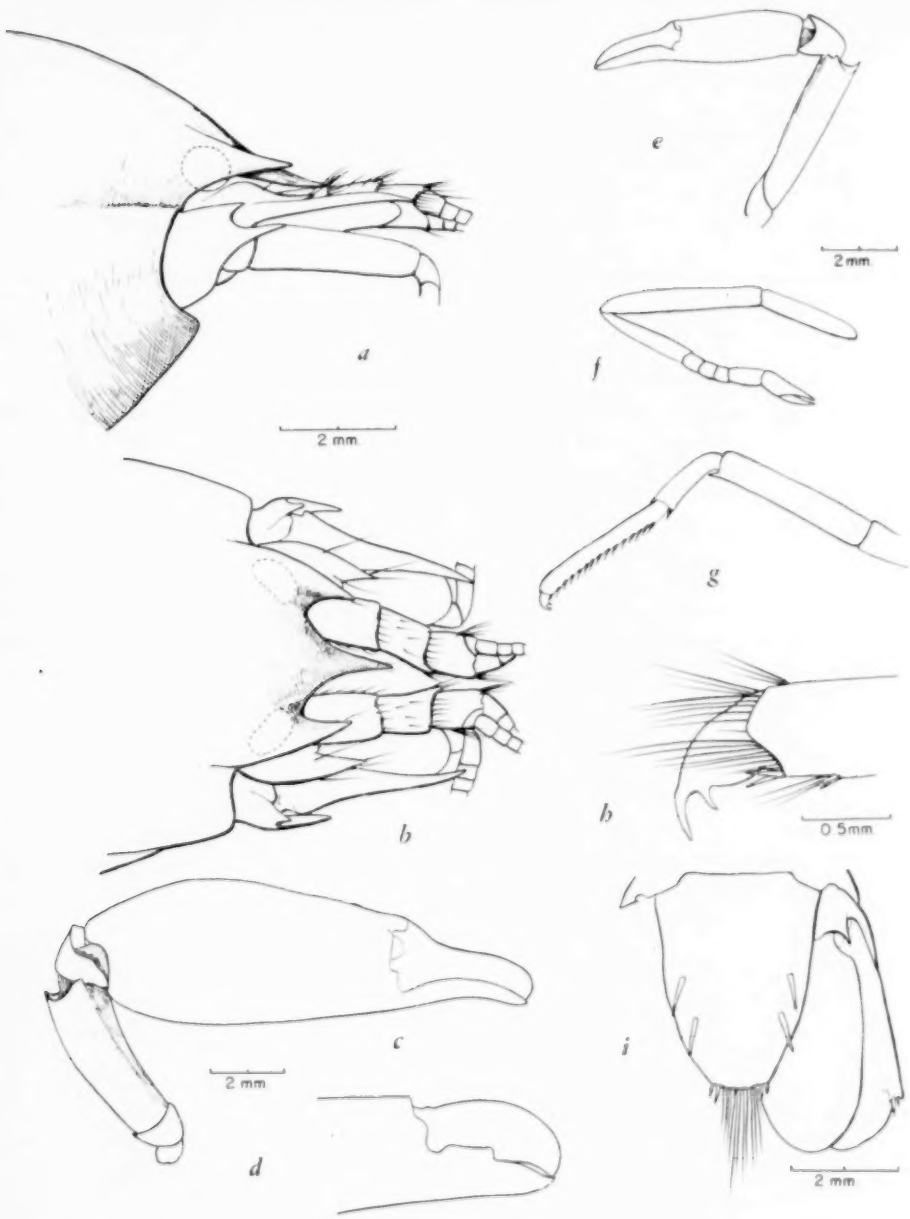

FIG. 2. *Synalpheus amboinae* (Zehntner). *a*, *b*, Anterior region; *c*, large cheliped; *d*, large chela, ventral view; *e*, small cheliped; *f*, second leg; *g*, third leg; *h*, third leg, dactylus; *i*, telson and uropods.

possibly the distinguishing characteristics may be the result of growth and therefore not of specific worth. However, in the absence of an intergrading series of specimens, the species has been permitted to stand.

Synalpheus consobrinus de Man, 1909

For synonymy see Banner, 1957.

LOCALITY: 8 specimens from GOC-53.

DISCUSSION: This group of specimens agreed well with the description and variations of de Man. In general they ran smaller than de Man's type, mostly 15 mm. long or less, yet the females were ovigerous. It is likely that these, together with the closely related *S. carinatus* (de Man) and *S. amboinae* (Zehntner), were collected from crinoids on the coral reef, but the exact data on their capture is lacking. In any case, it seems strange that three different but most closely related species would be living so close to each other in the same basic habitat, and for that reason alone the species should be suspect.

Synalpheus charon (Heller), 1861

Synalpheus charon obscurus Banner, 1956

For synonymy see Banner, 1956.

LOCALITY: 3 specimens at GOC-51, two of *S. charon charon*, one of *S. charon obscurus*.

DISCUSSION: The fact that in this locality two specimens of *S. charon charon*, an ovigerous female and a male, and one ovigerous female of *S. charon obscurus* were found casts some doubts as to the validity of the subspecies. It may indicate that the two forms are mere variations that breed together; it certainly indicates that the subspecies are not geographically distinct, as the other collections have indicated until now. However, as no intergrading specimens have been found and as the data of this collection do not indicate that the two subspecies might not maintain an ecological isolation, it has been decided to leave the subspecies standing.

Synalpheus paraneomeris Coutière, 1905

For synonymy see Banner, 1956.

LOCALITIES: 3 specimens at A-7; 5 specimens at GOC-51.

Synalpheus coutièrei Banner, 1953

For synonymy see Banner, 1957.

LOCALITY: 1 specimen at GOC-55.

Synalpheus pachymeris Coutière, 1905

Synalpheus biunguiculatus var. *pachymeris*, Coutière, Fauna and Geog. Maldive and Laccadive Archipelagoes 2(4): 873, pl. 71, fig. 9, 1905.

Synalpheus pachymeris de Man, Siboga Exped. 39a^1(2): 199, 1911.

LOCALITY: 1 ovigerous female from GOC-55.

DISCUSSION: This sole specimen agrees well with Coutière's description and figures except that the orbital teeth are more pointed, with their outer lateral margins concave, similar to that figured by de Man for *S. quadrispinosis* de Man (1911: pl. 12, fig. 57).

Synalpheus quadrispinosus de Man

Synalpheus quadrispinosus de Man, Nederland. Dierk. Ver., Tijdschr. II, 11(4): 298, 1910; also, Siboga Exped. 39a^1(2): 285, pl. 12, fig. 57, 1911.

Synalpheus quadridens de Man, Nederland. Dierk. Ver., Tijdschr. II, 11(4): 299, 1910; also, Siboga Exped. 39a^1(2): 284, pl. 12, fig. 56, 1911.

LOCALITY: A male and an ovigerous female from GOC-55.

DISCUSSION: de Man described as separate species two closely related forms, both characterized by four spines on the posterior margin of the sixth abdominal segment. They were separated by a series of characteristics, but principally by the form of the orbital teeth and the proportions of the small chela.

The first species, *S. quadrispinosus*, was represented in the Siboga collections by three mature and two immature specimens; the second, *S. quadridens*, by a sole ovigerous specimen lacking the large chela.

In this collection there is a single pair of specimens in good shape (although the male is lacking the small chela) which exhibits a perplexing confusion of the supposedly distinguishing characteristics of the two species as separated by de Man.

Rostrum and orbital hoods: Both specimens are very similar to *S. quadridens*, with the orbital teeth heavy and inflated.

Antennular peduncles: In both specimens the antennular peduncle is assymetrically developed, with the total lengths of the peduncles approximately the same, but with the basal article of one about 1.3 times the length of the other; however, in general appearance the articles are slender as reported for *S. quadrispinosus*. The stylocerite, to the contrary, is shorter and heavier like that of *S. quadridens*.

Antennae: In the male the scaphocerite is shorter than that of *S. quadrispinosus* (which had the shorter scaphocerite of the two species), while in the female it is longer than *S. quadridens*. The carpocerite is shorter in the male than *S. quadridens* (which had the shorter carpocerite), while in the female the article is long as in *S. quadrispinosus*.

Large chela: In *S. quadrispinosus*, the only species with the large chela described, the chela had a breadth of 0.34 its length, the fingers occupied the distal 0.27 of the length (recalculated from de Man), and there was a rounded-to-acute tooth above the dactylar articulation. In both of these specimens the proportions are exactly the same, with the breadth 0.25 the length, and with the fingers occupying the distal 0.26 the entire length of the chela. In the male the tooth above the the dactylar articulation is heavy and very conspicuous; in the female it is less pronounced and more gradually rounded.

Small chela: This is present only in the female, where the carpus equals 0.33 the length of the chela; the chela is 3 times as long as broad, with the fingers occupying the distal 0.4. These proportions are close to those of *S. quadrispinosus*, but not exactly the same.

Third leg: In the merus, where the greatest differentiation occurs, the male is 3 times as long as broad, like *S. quadridens*, and the female is 3.8 times as long as broad, like *S. quadrispinosus*.

Sixth abdominal segment: In the male the lateral teeth are narrow and acute like *S. quadrispinosus*, while in the female they are broader and more rounded like *S. quadridens*.

Telson: The proportions are given in the table below:

	MALE	FEMALE	*S. quadrispinosus*	*S. quadridens*
Length/breadth at base	1.3	1.3	1.5*	1.4*
Breadth at base / Breadth at tip	1.7	2.0	2.1–2.2	2.0
Length/breadth at tip	2.3	2.5	3.2–3.4	2.8

(*Ratios calculated from other ratios.)

From this it can be seen that the telson most closely approached that described for *S. quadridens*.

In summation, the specimens at hand are quite similar to *S. quadridens* in five characteristics, and to *S. quadrispinosus* in five other characteristics. Even if these were not a cohabiting pair—which they probably were, considering that they were collected together—their essential similarities would not permit them to be considered as other than a single species. Their similarities to both *S. quadrispinosus* and *S. quadridens* should establish their close relationship to both of de Man's species and their variable and inconsistent differences with both of de Man's nominal species destroys the validity of de Man's criteria for separation of the two forms. The only conclusion that may be drawn logically is that *S. quadridens* is a synonym (by page priority in the original description) for *S. quadrispinosus* and that *S. quadridens* is a variable species.

ALPHEUS Fabricius

Megacheles Group

Alpheus oahuensis Banner, 1953

Fig. 3

For synonymy see Banner, 1956.

LOCALITY: 1 specimen at GOC-51.

DISCUSSION: It is with considerable doubt that this specimen, a 11 mm. male, is assigned to this species. The rostral front, assymetrically developed in this specimen, is the same as that of *A. oahuensis*, but the articles of the antennular peduncles are shorter and relatively broader. The merus of the large chela is also slightly heavier, and the tooth on the distal inferior margin is rounded and without an acute tooth. The chela itself is of the same basic form, but more slender in this specimen, and the teeth flanking the articulation of the dactylus are not as well developed. In the small chela the greatest differences occur, for there the fingers are equal in length to the palm, instead of being 1.4 times as long, and are not thin and markedly curved, and do not bear the rounded ridge like those of *A. oahuensis*. The second legs are lacking. In the third legs the armature is similar but the legs are thinner, with merus 6 times as long as broad instead of 3.4 times; the inferior unguis of the dactylus is smaller.

But in spite of these differences in proportion, the general appearance of the two forms is quite similar, and these differences may be due to growth differences, for the type is 27 mm. long. Moreover, some variation along these lines was found in the paratypic series from Hawaii. However, with only one specimen from Onotoa, it is impossible to decide whether these differences are from individual variation, or from growth, or are constant differences that would be worth subspecific or specific rank.

Alpheus collumianus medius Banner, 1956

For synonymy see Banner, 1956.

LOCALITY: 2 specimens at GOC-51.

Machrochirus Group

Alpheus gracilis var. **simplex** (Banner), 1953

For synonymy see Banner, 1956.

LOCALITY: 1 specimen from GOC-51.

DISCUSSION: This single specimen agrees

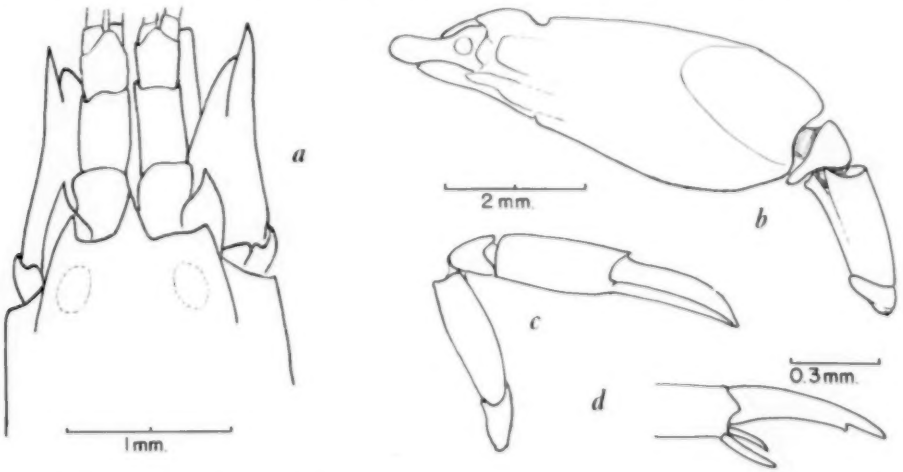

FIG. 3. *Alpheus oahuensis* (Banner). *a*, Anterior region; *b*, large cheliped; *c*, small cheliped; *d*, dactylus, third legs.

well with the specimens from Hawaii except that the dactylus of the third leg, instead of bearing a smooth convexity, carries an exceedingly small secondary unguis similar to but smaller than that found in *C. brachymerus* Banner (1953: fig. 17j). The external spine of the uroped is colorless.

In considering the specimens from Saipan, Arno, and Onotoa, the question arises as to the taxonomic level of this form. Obviously it is closely related to the *A. gracilis* of Heller, but whether it should be considered as a separate species, as a geographical subspecies, or as a variant—as it is now described—of the basic species, cannot easily be determined. On the basis of the Hawaiian specimens alone it would appear to be a separate species, or at least a subspecies; however, the specimens are from wide-spread localities. Yet none of these extra-Hawaiian forms are exactly like the specimens from Hawaii. It is possible that each of the studied archipelagoes have populations that could be interpreted as separate subspecies; certainly these variations appear to validate the consideration of these or the Hawaiian form as separate species. Yet the samples from the other archipelagoes have not been extensive enough to draw any conclusions about the populations, and many areas of the Pacific have not been sampled at all. Therefore the form is left as it was described originally with a tentative infrasubspecific designation.

Alpheus ventrosus Milne Edw., 1837
Fig. 4

For synonymy see Banner, 1956.

LOCALITIES: 2 specimens at GOC-22, 1 at GOC-33, 2 at GOC-36, 7 at GOC-51.

DISCUSSION: This group of four specimens from GOC-51, together with specimens from Saipan and Arno, present an almost complete intergradation between the small (8.5 mm.) form described as *A. latipes* and *A. ventrosus* which reaches a length of more than 40 mm.

While *A. latipes* as described was similar in general configuration to *A. ventrosus*, the two were distinctly separated by a number of characteristics. In the front of the carapace in *A. latipes*, the rostral carina was narrow and sharp and the orbital teeth were confluent with the front of the carapace, instead of having a flattened rostral carina and having the orbital teeth demarked medially from the margin of the carapace as is a characteristic for *A. ventrosus*. The antennular peduncles and the second and third legs were relatively broader in *A. latipes*. The fingers of the large chela were relatively shorter and the merus of the large and small chela were feebly armed or completely unarmed in *A. latipes*, instead of bearing up to four or five strong spines as in *A. ventrosus*. The dactylus of the third leg was abruptly curved and strongly acute in *A. latipes*, while in *A. ventrosus* the dactylus was of a peculiar blunt form, with a growth on the tip that was reminiscent of a horse's hoof. (Compare figs. 27, 28, Banner, 1953.)

Yet this group of specimens, ranging in size from 8.2 mm. to the adult size, shows an almost perfect intergradation in all of these characteristics. Two of the most marked and most easily observed characteristics, the form of the rostral carina and the form of the dactylus of the third legs, were chosen for detailed study and illustration. The four smaller specimens came from the station mentioned above; the last specimen came from the author's collection from Saipan.

In the 8.2 mm. specimen, the parts are almost identical to those described for *A. latipes:* if anything the dactylus of the third leg is slightly thinner. In the 9.7 mm. specimen the rostral carina does not change, but the dactylus is developing some extra superior and inferior thickenings. In the 10.8 mm. specimen the rostral carina still remains constant, but the dactylus is definitely growing thicker, the hook smaller, and a superior and inferior ridge is becoming more marked. In the 15.4 mm. specimen the interorbital portion of the rostral carina is broader and flatter,

but it still remains a sharp ridge on the anterior portion of the rostrum; the dactylus retains only a trace of the hook, the superior ridge is well developed, and the "hoof" is developing; the last spines of the propodus are thickening, but remain acute. Finally, in the 16.2 mm. specimen, the rostral carina is flattened to the tip of the rostrum, but still not as broad as in the full-sized adults; the dactylus has the structure and proportions of the adult; the last spines of the propodus are broad, distally rounded, but are not yet excavate on the tips, as are found in the mature specimens.

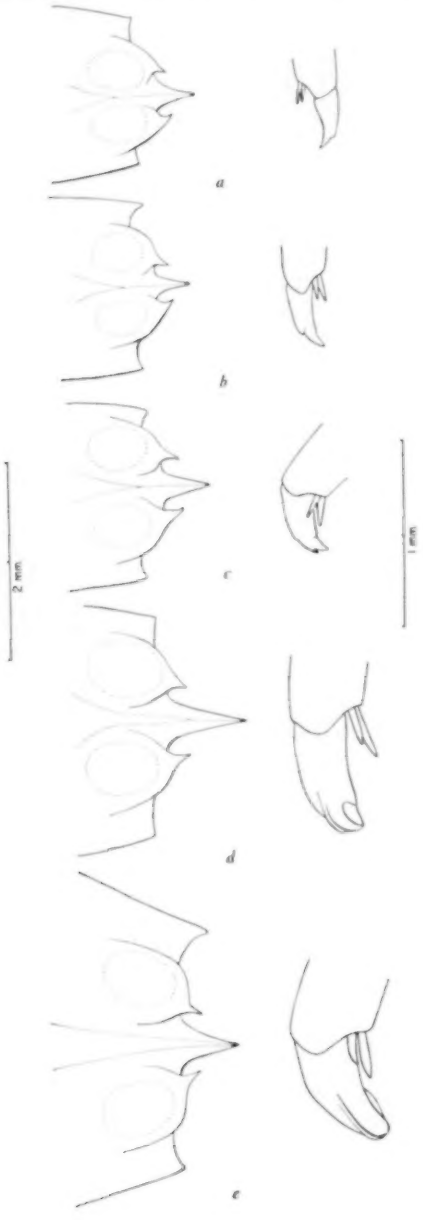

FIG. 4. *Alpheus ventrosus* Milne-Edwards, to show developmental stages in the form of the rostrum and dactylus of third legs. *a*, An 8 mm. specimen; *b*, a 9.7 mm. specimen; *c*, a 10.8 mm. specimen; *d*, a 15.4 mm. specimen; *e*, a 16.2 mm. specimen; *a–d*, from Onotoa, *e*, from Saipan; carapaces and dactyli with separate scales. (Note: Dactyli are in differing rotation.)

This easily recognizable species, possibly one of the most distinctive species of the genus, appears to have had at least four names applied to it: *A. lottini* Guérin, 1826–1830 (by Stebbing and Barnard, see below); *A. ventrosus* H. Milne-Edwards, 1837; *A. laevis* Randall, 1839; and finally, as discussed above, *A. latipes* (Banner), 1953. Unfortunately the three early names were published with short and generalized descriptions; only the first description carried a figure, and this figure appears to have been inaccurate.

The type specimen of Randall for *A. laevis* probably is lost with the rest of the early types at the Philadelphia Academy of Science, but there is only one species from Hawaii, the type locality, that meets the qualifications of his description including that of size ("length about 1½ inches"). This species is the one now known as *A. ventrosus* (see Banner, 1953: 84, fig. 28).

The type of Milne-Edwards has never been formally redescribed, but its characteristics are known. In *Les Alpheidae* (1899) Coutière discusses and figures specimens that he identifies as *A. laevis* Randall (figs. 54, 201, 251, 263, 307, 324, 325), a form plainly identical with the species from the Hawaiian Islands that has been known as either *A. laevis* or *A.*

ventrosus. Especially noteworthy are the figures of the dactyli of the third to fifth legs (fig. 324, 325), a characteristic unique within the genus. Then Coutière (1905: 882) reported, "L'examen des types de H. M. -Edwards ne permet aucun doute sur l'identite de l'*A. ventrosus* et de l'espece . . . *A. laevis* . . . Randall." There appears, therefore, no question but that the two names refer to the same species.

However, there is considerable question whether the form described as *A. lottini* by Guérin is this species. Milne-Edwards in his original description of *A. ventrosus* (1837: 353) concludes by saying, "L'Alphée de Lottin dont il a été publié une bonne figure, mais dont la description n'a pas encore paru [the named figure was published about 10 years before the printed description, and in the meantime Milne-Edwards published his work] paraît être très-voisine de l'espèce précédete." Stebbing (1915: 82) states, "But the description of *A. ventrosus* does not seem to justify any claim for the priority of that name over Guérin's *A. lottini*." He therefore used the name *A. lottini*. Barnard, in his work on the South African decapods (1950: 748, fig. 141), follows the name used by Stebbing.

However, while Guérin's description and figures do not show any great differences from the generalized description of Milne-Edwards, they do show differences from the form now recognized as *A. ventrosus* and from the types as re-examined by Coutière. In Guérin's figure, the rostrum in *A. lottini* reaches almost to the middle of the second antennular article, instead of to the distal part of the first article; the lateral spine of the scaphocerite is too prominent; the second article of the carpus of the second leg is about 6 times as long as broad instead of 1.5 times; the dactyli of the third to fifth legs are shown as definitely acute. In the description, the wrist of the large chela is described as elongate and cylindrical, instead of short and cyathiform, and the articles of the posterior legs also as cylindrical instead of compressed. A most important difference is in the color, for the orange-red color of the specimens of this species is one of the most constant colors found in the family, yet Guérin figured it as a delicate lettuce green and described it, "Sa couleur est d'un jaune verdâtre dans l'alkool." It should be noted, too, that the figure does not show any orbital spines, yet Guérin reports these in his description.

It is possible, of course, that these differences are the result of inaccurate description and the types are actually identical; however, there is no reason to presume so, and until the time that Guérin's types are found and redescribed, the name *A. ventrosus* should be accepted. If the types of Guérin should be found to be identical with the species of Milne-Edwards, I would recommend that the little-known and almost never used earlier name be suppressed by the International Commission on Zoological Nomencalture in favor of the long accepted name of this, one of the most common species of the genus.

One other problem raised by Stebbing (*loc. cit.*) was concerned with the identity of the form that Bate called *A. laevis* Randall. "Bate's figure of *A. laevis* in the 'Challenger' report [1888: 555, pl. 99, fig. 3] cannot easily be reconciled with the species here in question." It is true that Bate neither figured nor described the peculiar unguis of the third to fifth legs, and he depicted the legs, especially the second legs, as much too thin, but otherwise the specimen appears to agree with *A. ventrosus*. Moreover, Bate's specimen came from Hawaii, and, as with Randall's specimen, there are no other species in Hawaii that agree even moderately well with the description and figures. It should be noted, also, that Bate shows dark spots on the superior surface of the large and small chelae, a characteristic of the species (cf. Banner, 1953: fig. 28 c, d, e).

The last question that might arise is whether the species identified by Stebbing and Barnard from South Africa as *A. lottini* is the same as *A. ventrosus*. Stebbing's brief description leaves little room for doubt, and Barnard's

excellent figures make it certain that the South African form does not differ in any significant fashion from the Pacific form.

Alpheus machrochirus Richters, 1880

For synonymy see Banner, 1957.

LOCALITY: 1 specimen at GOC-36.

Obesomanus Group

Alpheus lutini Coutière, 1905

For synonymy see Banner, 1956.

LOCALITIES: 1 specimen each at B-4, GOC-28, GOC-53, GOC-55.

Alpheus species

LOCALITY: 2 specimens from GOC-51.

DISCUSSION: These two specimens, both females, appear to be in either the *Obesomanus* group or the *Crinitus* group, and may be related to the complex containing the species *A. obesomanus* Dana, *A. microstylus* (Bate), and *A. lutini* Coutière. These specimens appear to be of a separate species, possibly new, but preliminary work on the variation in this complex indicates that the specific characteristics need re-evaluation. Therefore it has been considered wiser to defer judgement on these specimens until a later paper when the related species are considered.

Crinitus Group

Alpheus brevipes Stimpson

Alpheus brevipes Stimpson, Acad. Nat. Sci. Phila., Proc. 12: 30, 1860.
Crangon brevipes Banner, Pacific Sci. 7(1): 103, figs. 35, 36, 37, 1953 [neotype described].

LOCALITY: 2 specimens at GOC-51.

Alpheus bucephalus Coutière

For synonymy see Banner, 1956.

LOCALITY: 3 specimens at A-7.

DISCUSSION: These specimens exhibited a variation similar to those forms reported upon from Saipan.

Alpheus clypeatus Coutière

Alpheus clypeatus Coutière, Fauna and Geog. Maldive and Laccadive Archipelagoes 2: 897–898, pls. 81, 82, figs. 36, 36g, 1905.
Crangon clypeata Banner, Pacific Sci. 7(1): 107, figs. 37, 38, 39, 1953.

LOCALITY: 1 specimen at GOC-51.

Alpheus pachychirus Stimpson, 1860

For synonymy see Banner, 1956.

LOCALITY: 1 specimen at GOC-51.

Diadema Group

Alpheus diadema Dana, 1852

For synonymy see Banner, 1956.

LOCALITY: 1 specimen at GOC-36.

Alpheus lanceloti Coutière

Alpheus lanceloti Coutière, Fauna and Geog. Maldive and Laccadive Archipelagoes 2: 900, pl. 83, fig. 39, 1905.

LOCALITY: 1 specimen only from A-3.

DISCUSSION: This specimen, fortunately intact, agrees almost perfectly with the original description by Coutière. The only exception may be in the merus of the large cheliped, which Coutière shows as bearing four immovable denticles proximal to the terminal denticle, and which bears four short but heavy movable spines in this specimen. It should also be noted that the merus of the third leg on one side is like that of the type bearing three movable spines, while on the other side there are four such spines.

Alpheus gracilipes Stimpson, 1860

For synonymy see Banner, 1956.

LOCALITY: 2 specimens from GOC-22.

Alpheus paracrinitus (Miers) **bengalensis** Coutière, 1905

For synonymy see Banner, 1956.

LOCALITY: 1 specimen from A-10–12.

Edwardsii Group

Alpheus crassimanus (Heller), 1865

For synonymy see Banner, 1957.

LOCALITY: 1 specimen from A-1.

DISCUSSION: This single specimen is a female and the identification therefore lacks the confirmation obtainable only by the examination of the small chela of the male; however, on all characteristics it is similar to specimens of the same size from Hawaii (see Banner, 1953: 134).

Alpheus strenuus Dana, 1852

For synonymy see Banner, 1957.

LOCALITY: 2 specimens from A-3.

DISCUSSION: Special efforts were made to collect large specimens, presumably of this species, from the windward reef flat where they were abundant. However, it was found impossible, for they lived in burrows in consolidated coral where a geologist's pick would scarcely penetrate.

The Gilbertese on the island informed me that they used this shrimp—and some other species of small chelate shrimp-like crustaceans that I was unable to collect—as food. The shrimp were caught in the back-ridge trough of the windward reef with nets at night when torch fishing. The collective name for this group of decapods is "Teniwarowaro," and my informant stated that their size ranged to 14 inches long (235 cm.). The Gilbertese ate the cephalothorax and abdomen of the shrimp.

Alpheus pacificus Dana, 1852

For synonymy see Banner, 1956.

LOCALITIES: 1 specimen at A-2, 40 at A-3, 3 at A-6, 1 at A-7.

DISCUSSION: Some of the specimens placed in this species are lacking their small chela, so that they can not be positively identified. However, they agree on other characteristics with the complete specimens.

In this group of specimens slight sexual dimorphism is found in the proportions of the small chela, with the fingers of the male being relatively longer (up to twice as long as the palm) than in the female where they are about 1.5 times as long as the palm. However, the characteristic is not constant, especially for those of smaller size where the finger length is quite variable between these limits.

Alpheus dolerus Banner, 1956

For synonymy see Banner, 1956.

LOCALITY: 2 specimens at GOC-51.

DISCUSSION: The finger of the small chela of the male bears a fringe of setae that reaches about half the length of the dactylus on the inner face and a shorter distance on the outer face; this fringe is similar to the fringe of the "balaeniceps-type" chela except that it is continuous over the superior surface of the finger and the finger is not expanded. Otherwise the two specimens are like those of Saipan.

Alpheus parvirostris Dana, 1852

For synonymy see Banner, 1956.

LOCALITIES: 1 specimen at GOC-22, 3 at GOC-28.

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[3] These are the title page dates, and evidently do not correspond to the actual dates of publication; however, there appears to be some difference of opinion as to the actual dates of publication.

Records of Scattering Layers from New Zealand Seas

B. M. Bary[1]

Hitherto the scattering of the ultrasonic pulses of echo sounding equipment attributable to biological agency (Johnson, 1948; Kampa and Boden, 1954*b*) has not been recorded from New Zealand waters. However, Dietz (1948) reported on occurrences, over extensive areas, of the deep scattering layer in the Pacific and Antarctic oceans, and on this ground alone, the presence of scattering in New Zealand waters could be expected. Recent investigations of occurrences and distribution of plankton in New Zealand waters (Bary, in press) suggest an abundant zooplankton, and it would appear also that suitable hydrological conditions for the necessary concentrations of organisms may exist in the disturbed, mixed waters which occur within the New Zealand area. Again, large shoals of pelagic fish are frequently seen in the coastal waters. It is therefore consistent that records are available which show scattering of sound from both plankton and fish.

The notes which follow deal briefly with some of these records from New Zealand. Both deep and shallow scattering layers, multiple layering, and scattering from fish shoals are discussed. One record is believed to show scattering from layers of zooplankton which are associated with a shoal of fish. Other records illustrate two related phenomena, that of separated multiple layers maintaining their identities throughout the ascent to the surface at night, and the converse—the differentiation and subsequent descent of separate layers from the surface at dawn.

Acknowledgment

I am grateful to Mr. J. W. Brodie, Superintendent, New Zealand Oceanographic Institute, for granting access to the collection of fathograms housed at the Institute.

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Materials

The hydrographic survey being carried out by H.M.N.Z.S. "Lachlan" is a continuing source of fathograms of coastal and offshore waters. Other naval vessels and coastal and overseas merchant shipping have contributed many records from the high seas. "Lachlan" fathograms are particularly useful for shallow scattering records. The other shipping offers a source for deep scattering records, but in fact, no scattering has been detected in any of the fathograms from these ships. Some of the most useful records have originated in special investigations made in New Zealand waters by R.R.S. "Discovery II," of the National Institute of Oceanography, England, and by the Danish Expedition in H.D.M.S. "Galathea." I am most grateful for permission to reproduce records from both of these sources.

All examples of scattering have been obtained incidental to other requirements. For this reason the records are not always as clear as they might have been had the sounder been tuned to give maximum strength from the scattering layers. It is unfortunate, too, that promising records have been phased out in a number of instances; and additional difficulties are met in the fading of some fathograms made on iodide paper.

Scattering Layer Records

The localities and lineal extent of the records of scattering for the New Zealand area are shown in Figure 1. Figures 2 to 9 reproduce some examples, and a general summary of all occurrences is given in Table 1.

The ascents of the two shallow scattering layers are shown in Figure 2, a trace made

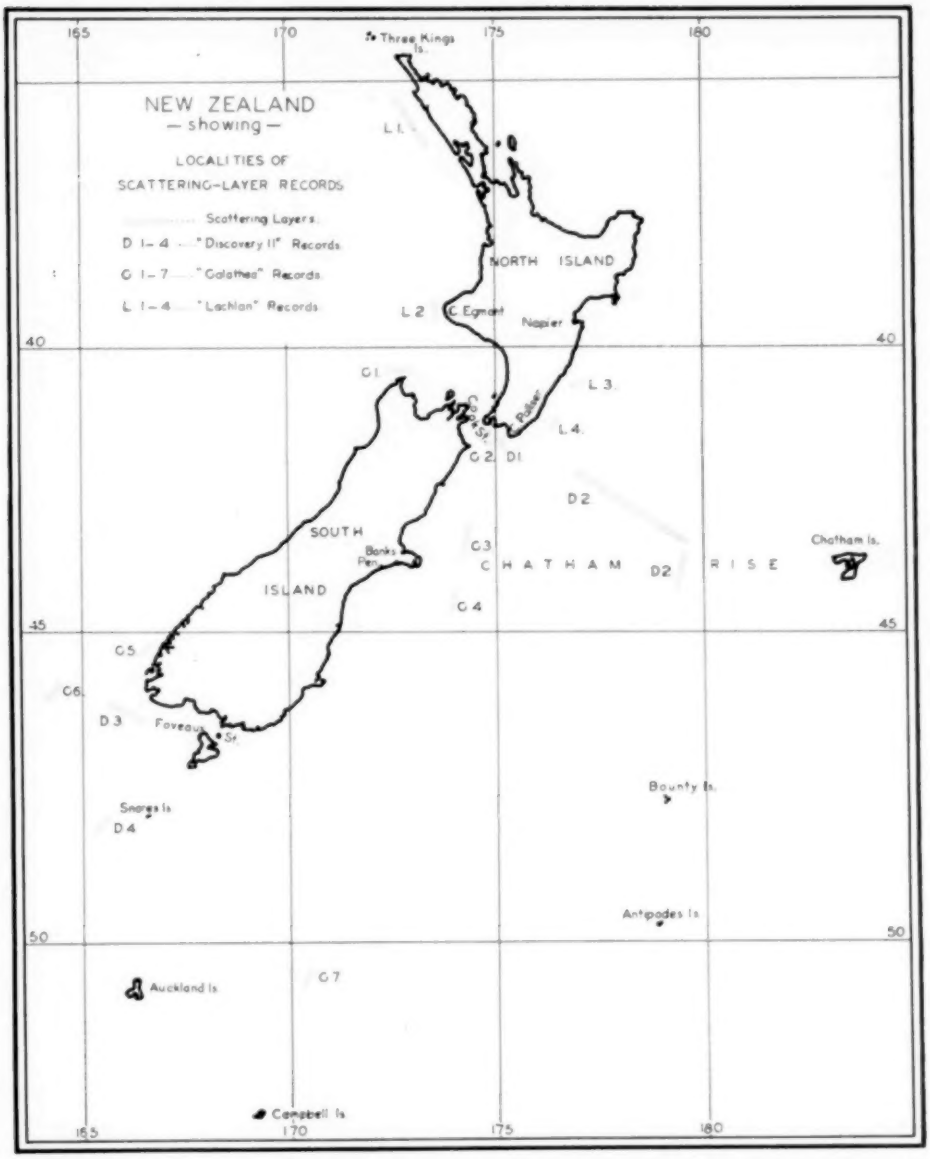


FIG. 1. The localities and approximate lineal extent of scattering layer records from New Zealand waters. All available records are shown (and see Table 1), but not all are otherwise referred to in the text.

from "Lachlan" in coastal waters, eastern North Island (L2, in Fig. 1). This is not a strong record, but two separate layers, each of which is broken into parts, are visible ascending between the bottom and the surface. Rate of ascent for both layers is at ap-

TABLE 1
SOME FEATURES OF THE SCATTERING RECORDS FROM NEW ZEALAND SEAS

RECORD NO.	FIG. NO.	SHIP	DATE	TIMES	DEPTH OF WATER, (M.)	NOTES ON LAYER(S)	DEPTH OF SCATTERING, (M.)	RATE OF MOVEMENT, M./MIN.	POSSIBLE NATURE OF ORGANISMS
L1	..	H.M.N.Z.S. "Lachlan"	11.V.54	2330–2345	530–402	Brief appearance of a single layer in ascent	73	..	Plankton and possibly fish
L1	..	"	12.V.54	0130–0230	349–256	Double layer, clear of bottom and stationary	Between 109 and 183	..	
L2	2	"	10–11.V.54	2130–2300	110*	Two widely separated layers ascending between bottom and surface	91–0	1.5	Plankton
L2	3	"	11.V.54	0645–0800	119–137	Single layer in dawn descent	0–122	2.1 m./min. and 1.3 m./min.	Plankton
L3	7	"	12.II.54	2135–2235	Approx. 1828	Some multiple layering. Layers descending then ascending in an anomalous manner	91*	..	Plankton
L4	4	"	23–24.II.54	0430–0500	128–343	Separated, multiple layers, 15 mins. apart, in descent	0–64 0–35	Approx. 2	Plankton and fish shoal?
G1	..	H.D.M.S. "Galathea"	21.XII.51	0645–0745	110–70	Stationary layers and shoals	Between 50 and 70	..	Plankton and fish
G2	..	"	27.XII.51	2000–2230	90–600	Layering and shoals, stationary and in ascent	30 m. and 70–200	..	Mixed fish and plankton?
G3	5	"	27.XII.51	0400–0515	960–530	Separated multiple layers in descent	0–200	1.3 and 0.6	Plankton
G3	..	"	27.XII.51	0610–0700	570–380	Uneven shoals, lying parallel with the bottom	From 300–200	..	Fish?

TABLE 1—*Continued*
SOME FEATURES OF THE SCATTERING RECORDS FROM NEW ZEALAND SEAS

RECORD NO.	FIG. NO.	SHIP	DATE	TIMES	DEPTH OF WATER, (M.)	NOTES ON LAYER(S)	DEPTH OF SCATTERING, (M.)	RATE OF MOVEMENT, M./MIN.	POSSIBLE NATURE OF ORGANISMS
G4	6	H.D.M.S. "Galathea"	28.XII.51	1100–1244	330–540	Single layer at daylight level	Between 280 and 140	..	Plankton
G5	..	"	13.I.52	1900–2022	4300+	Deep, patchy layer, ascending and descending irregularly	Between 300 and 3000	..	Fish, or sounder fault?
G6	..	"	13.I.52	0915+	200	Short, dense layer lying near to and parallel with the bottom	200+	..	Probably fish
G7	..	"	29–30.XII.51	2400–0100	520	Faint scattering in mid-depths	Between 100 and 200	..	?
D1	..	R.R.S. "Discovery II"	2.XI.50	1630–1715	640–128	Faint to strong scattering at day level. Layer intercepts slope of shelf	238–183	..	Possibly plankton
D2	..	"	3–4.XI.50	0245–0830	519–366	Scattering in the surface waters, during descent, and at daylight level of 183 to 238 m.	Between 0 and 183–238	2.6	Plankton
D2	..	"	4–5.XI.50	0930–1207	311	Scattering stationary at daylight level	183	..	Plankton
D3	8 and 9	"	26.V.51	1650–1720 1845–55 1900–2130	128–338	Mixed shoals and layering. Scattering layers ascending, 2.0 m./min.	186–109	2.0	Plankton and fish
D4	..	"	11.XII.50	1656–1740	354–429	Faint scattering, parallel to, and near, deepening bottom	320–356	..	Fish?

proximately 1.5 m. per minute. The first begins to ascend at about 2130 hours, arriving at the surface around 2240; the second layer begins 15 min. later than the first and arrives at the surface at 2300 hours. Depth of water is between 102 and 124 m. The nighttime concentration of organisms at the surface is masked by the transmission signal. However, marked concentration in depth becomes apparent in the 15 to 20 minutes preceding the dawn descent (Fig. 3. This record is part of that shown in Fig. 2). This single layer begins to descend at 0645 hours. Downward migration is approximately 2.1 m. per min. during the first 30 minutes, but over the next 45 minutes the rate is slower, at approximately 1.3 m. per min. The layer retains its entity for a short while after it has reached the bottom.

Early stages in the descents of two separate layers are illustrated in Figure 4, a "Lachlan" trace from north of Cape Palliser (L4, in Fig. 1). The first layer descends clear of the transmission signal at approximately 0430 hours and after a short descent appears to split into two layers. One of these two appears to join with a second, dense layer which begins to descend about 15 minutes later than the first. Rate of descent is at about 2 m. per min. In a "Galathea" record made over the Chatham Rise and shown in Figure 5 (G3, in Fig. 1), two separate layers, preceded by a dense surface concentration, are shown during the dawn descent. The downward migration commences about 0400 hours and is strongly in evidence by 0500 hours. Both layers appear to split into two. Rates of descent approximate 1.3 and 0.6 m. per min. respectively for the first and second layers. The record rather abruptly fades out at 0515 hours.

A second "Galathea" record, Figure 6, shows a scattering layer at its daytime level. At its deepest the layer is at about 183 m., but its depth varies considerably. This record was made between 1100 and 1230 hours in

FIG. 2. The evening ascent of two separate layers in shallow coastal waters—the southern end of "Lachlan" record, L2, in Figure 1.

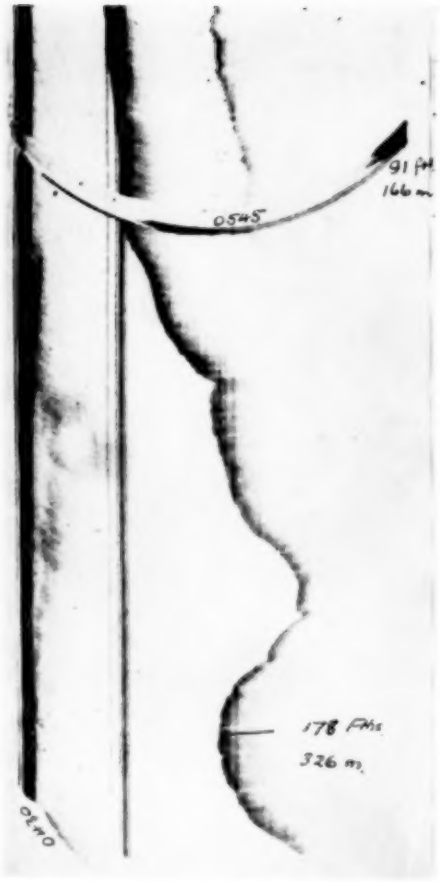
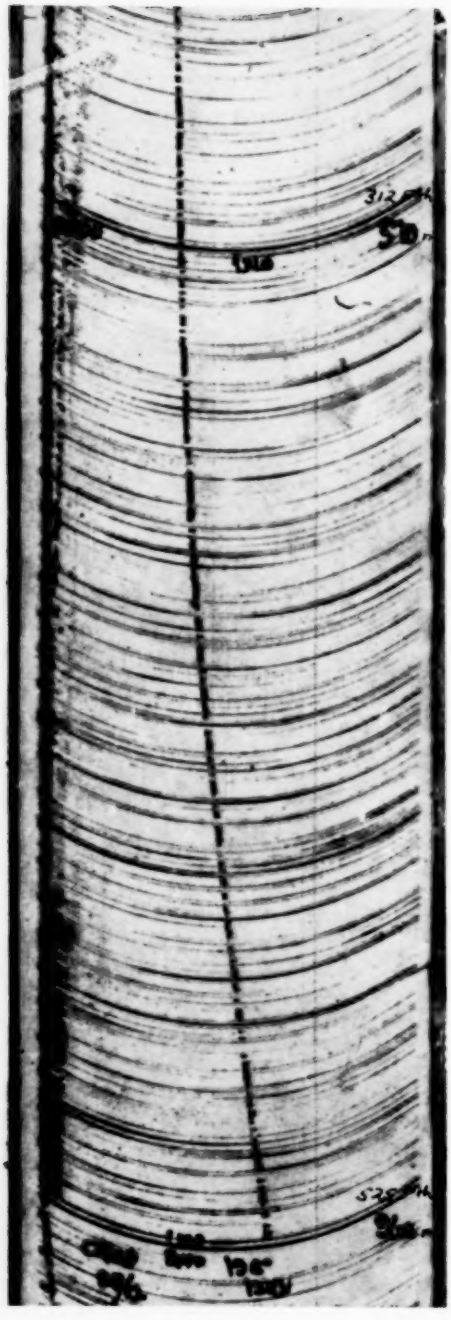


FIG. 4. The dawn descent of two separate layers, the first of which also splits into two; "Lachlan" record, L3.

water of 330 to 550 m. seaward of Banks Peninsula (G4 in Fig. 1).

Examples of more or less anomalous behaviour of layers are shown in Figures 7 and 8. Figure 7 is from a "Lachlan" fathogram made south of Napier (L3, in Fig. 1). It illustrates a scattering layer which is descending to a deeper level between 2135 and 2155 hours at which depth it becomes stationary

FIG. 3. The dawn descent. Note the concentration of organisms in depth prior to the differentiation and descent of the layer; the northern end of "Lachlan" record, L2.

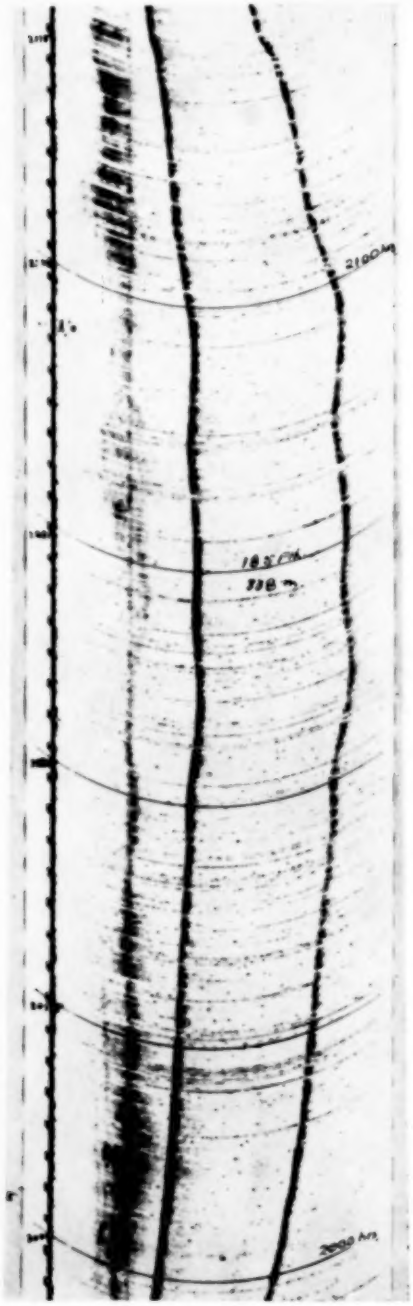


for 15 minutes (around 2200 hours), and then rises slowly. Sunset was at 1930 hours (mid-February, 1954) and darkness would have fallen about an hour before this trace was commenced. The trace is of even texture with a suggestion of subsidiary layers within the main one; it is probably the result of scattering from zooplankton. If so, the record illustrates a curious reversal in the expected direction of movement of the organisms. It is possible that this special reaction is an effect of moonlight. The moon was in the first quarter and crossed the meridian at about 2130 hours on the day in question.

A "Discovery II" record (Fig. 8) made when approaching Foveaux Strait from the west (D3, in Fig. 1) is of strongly developed scattering most of which is remaining at depth. Sunset was at 1700 hours (May 1951), there was no moon, and it would have been dark for some time before 1950 hours when the record begins. The unevenly distributed, dense patches in this trace suggest that fish may have been the chief cause of the scattering. Fish do not necessarily perform diurnal migrations, and thus the fact that the main body of the scattering organisms is not ascending might be explained. On the other hand, three or four distinct layers can be detected in the earlier (left-hand) one-fifth of the record. These penetrate the fish scattering and are ascending towards the surface at rates of 2.0 to 2.5 m. per min. Their appearance is suggestive of scattering from planktonic organisms. This record may be indicative therefore of fish following and feeding on concentrations of plankton which are undergoing normal vertical migration.

Some other records are available, believed to be of scattering from fish shoals. Figure 9 illustrates one such record, made in the western approaches to Foveaux Strait by "Discovery II," earlier on the same day as that

FIG. 5. The dawn descents of separated layers followed by splitting of each of the layers. The heavier trace in the second layer is suggestive of larger animals being present; "Galathea" record, G3.



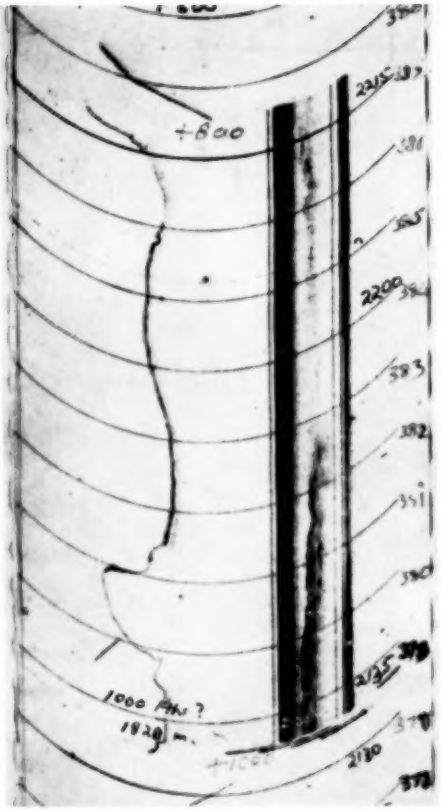


FIG. 7. Anomalous behaviour of a scattering layer during darkness. At first it is descending deeper into the water, and then begins to rise again. The phasing of the sounder has displaced the transmission signal down the fathogram; "Lachlan" record, L3.

shown in Figure 8. The dense shoal (marked "Fish?") would appear from its uneven denseness and patchiness, to be a large fish shoal, which then extends at lesser concentrations more or less parallel to the bottom. In view of the subsequent history of this zone of scattering—the record is continuous with that in Figure 8—it is possible that other pelagic organisms are contributing to it as well.

FIG. 6. A scattering layer maintaining a fluctuating daylight level in moderately deep water over the Chatham Rise; "Galathea" record, G4.

FIG. 8. Probable fish records combined with layers of plankton (on the left of the record). The latter are visible as three or four ascending layers cutting through the dense fish record; "Discovery II" record, D3.

DISCUSSION

Investigations of sound scattering of biological origin are being pursued for their bearing on studies of animal behaviour, distribution and ecology (Hersey and Moore, 1949; Moore, 1950), physiology (Kampa and Boden, 1954*a*; 1954*b*) and on fisheries biology (Richardson, 1952; Haffner, 1952). Not all of the physical characteristics of those invertebrate organisms which cause scattering are understood as yet (Smith, 1951, 1954), but the air bladder in certain fish is regarded as an excellent scatterer of sound (Marshall, 1951; Hersey and Backus, 1954). The principles emerging from investigations into these various aspects of the subject may be generally applicable, but such principles are only to be derived from specific, detailed observations from many different localities.

Scattering layer development may vary from one area to another. Some of the variation is attributable to the distributions of the different organisms which are able to effect the scattering. Moore (1950) has discussed such variations in scattering in relation to the distributions of several species of euphausiids in the north Atlantic. On the other hand, strong development of layers could result from those high concentrations of animals which may be associated with areas in which intermixing of contiguous bodies of water of differing properties is taking place. Thus localised scattering might well occur in the upwelling waters believed to be present at several localities about New Zealand (Garner, 1953). On a larger scale, scattering could be associated with the —possible—extensive disruption of the water layering and the resultant mixing of the waters where north-south moving masses cross the Chatham Rise (Fig. 1). This topographic barrier to unrestricted flow rises from about 2800 m. to within 450 m. of the surface and lies

athwart the direction of movement of the water masses. Relevant to these points, it is of interest to note that the present examples of scattering are predominantly from two areas where mixed waters are believed to be present. One of these is to eastward of South Island, and is associated with the supposed area of disturbed water from the Chatham Rise obstruction. Moreover, the subtropical convergence migrates seasonally across this area, although its relationship to present examples of scattering is not known. The second area, in the south west of South Island, is believed to be associated with mixing between waters of subantarctic and subtropical origins (Deacon, 1937).

The records presented from New Zealand waters appear to be similar in essentials to those made elsewhere. Their chief value lies in showing that development of scattering is fairly widespread in the area. Two features are noteworthy. Several records have illustrated the successive descents from the surface of two or more separate layers, and conversely, the ascents up to the surface of distinct layers. Development of multiple layering during the descent or ascent of a layer has frequently been recorded, but the writer is unaware of any published records in which such a separation into layers persists up to the surface, or develops at the surface prior to the descent of the organisms.

The second feature is illustrated in Figure 8. It is a matter for frequent conjecture whether scattering is caused by planktonic animals, notably euphausiids (Boden, 1950; Moore, 1950), or whether it is caused by predatory fish accompanying and feeding on planktonic organisms which are undergoing vertical migration (Hersey & Moore, 1949). In Figure 8, the large, dense masses of scattering have the appearance of fish shoals. Also, the distinct layers, present in the left-hand mass, are strongly suggestive of scatter-

FIG. 9. Probable fish record made earlier in the day than that in Figure 8; "Discovery II" record, D3.

ing of planktonic origin. If the two types of scattering have been caused by fish and plankton as is suggested, this is a record of fish which are associated with ascending planktonic concentrations.

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NOTES

An Unusually Large Salp

A large example of *Thetys vagina* Tilesius, solitary form, was captured in a 1-meter (mouth diameter) closing-type plankton net at a depth between 120 and 170 meters by the Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, on February 5, 1956, at 22° 15′N. latitude, 157°46′W. longitude. The specimen measured 306 mm. in length without processes and 333 mm. with processes. By water displacement its total volume equalled 278 ml.

This specimen is apparently larger than any salp previously known and is therefore considered worthy of note. The largest salps previously reported have had lengths as follows: *Thetys vagina*, solitary form, 226 mm. (Traustedt, 1885. *K. Danske Vidensk. Selsk., Skr., Naturv. og. Math. Afd.* 2(8): 337–400 [as *Salpa costata-tilesii*]); *Helicosalpa komaii* (Ihle and Ihle-Landenberg), solitary form, 230 mm. (Komai, 1932. *Kyoto Univ., Col. Sci., Mem.*, Ser. B. 8(1): 65–80 [as *Salpa virgula*]); *Salpa maxima* Forskål, solitary form, 230 mm. (Thompson, 1948. *Pelagic Tunicates of Australia*. Commenwealth Council for Scientific and Industrial Research, Melbourne. 196 pp.). In volume the largest specimen previously reported was a solitary form of *Helicosalpa virgula* (Vogt), 141 mm. in length, which measured 158 ml. in total volume by water displacement (Yount, 1954. *Pacific Sci.* 8(3): 276–330).

The nomenclature used in this note follows that of Yount (*ibid.*).—*Eugene L. Nakamura, Pacific Oceanic Fishery Investigations, U. S. Fish and Wildlife Service, Honolulu, Hawaii, and James L. Yount, Dept. of Biology, University of Florida, Gainesville, Florida.*

First Pacific Record of the Whale-louse Genus *Syncyamus* (Amphipoda: Cyamidae)[1]

The genus *Syncyamus* is known only from the central Gulf of Mexico, where it was taken from the surface of a false killer whale, *Pseudorca crassidens* (Owen) (Bowman, *Mar. Sci. Gulf and Caribbean Bul.* 5(4): 315–320). Recently a number of cyamids were collected from the blowhole and angle of the jaw of a dolphin which was shot in Panama Bay, 2 miles southeast of Tabogvilla Island. Mr. Franklin Sogandares-Bernal, Department of Zoology, University of Nebraska, who collected the cyamids, kindly forwarded them to the U. S. National Museum, where they have received catalogue number 99588.

Examination showed the cyamids to be members of the genus *Syncyamus*, differing only slightly from type specimens of *S. pseudorcae* Bowman. The Panama Bay specimens are smaller (length of largest ovigerous female, 3.0 mm.); the anterolateral margins of pereion somite 2 are more pointed, with the inner members of the produced double lobes longer than the outer; and pereion somites 6 and 7 are not coalesced dorsally, but separated by a distinct suture. The mouth parts are nearly identical with those of the Gulf specimens. With the limited material at hand, I am unable to determine whether the Panama Bay specimens should be separated specifically from *S. pseudorcae*.

The skull of the dolphin was badly damaged and was not preserved. Fortunately, Mr. Sogandares-Bernal made a color photograph of the dolphin, from which Dr. David H. Johnson, Curator, Division of Mammals, U. S. National Museum, has tentatively identified it as a young specimen of the long-snouted dolphin, *Stenella graffmani* (Lönnberg) a common dolphin in Panama Bay.

The present record is of interest not only because it is the second one for *Syncyamus* and

[1] Published with permission of the Secretary of the Smithsonian Institution. Manuscript received January 7, 1957.

the first Pacific record for this genus, but, insofar as I have been able to determine, because there are only five other published cases of cyamids infesting the small, toothed cetaceans commonly referred to as dolphins and porpoises. In four of these cases the cyamid involved was *Isocyamus delphinii* (Guérin-Meneville) and in three instances the hosts were unidentified dolphins (Guérin-Meneville, *Iconographie du règne animal*, II, pl. 28, fig. 5, 1836; Barnard, *Discovery Rpts.* 5:314, 1932). In one case the host was *Delphinus delphis* (L.) (Lütken, *K. Danske Vidensk. Selsk.* 10: 433, 1873). The other example is that of *Cyamus chelipes* Costa (*Mus. Zool. Univ. Napoli, Ann.* 3: 82, pl. 4, fig. 2, 1863), which was taken from an unnamed dolphin. Although Costa's figures are schematic, it is obvious from them that his species belongs in the genus *Syncyamus*. It is impossible to tell from Costa's account whether *chelipes* is conspecific with the Gulf of Mexico and Panama Bay specimens.

It is evident that additional collections of cyamids from porpoises and dolphins are needed for basic taxonomic studies, and those who have the opportunity to make such collections can greatly aid in filling in the gaps in our knowledge of these interesting amphipods.—*Thomas E. Bowman, Division of Marine Invertebrates, U. S. National Museum, Washington, D. C.*

Brighamia citrina (C. N. Forbes & Lydgate) St. John, comb. nov.

B. insignis Gray forma *citrina* C. N. Forbes & Lydgate, B. P. Bishop Mus., Occas. Papers 6 (4): 11(203), 1917. This plant in the Lobeliaceae, known only from the Haupu Range, Kauai, differs constantly from the only other species, *B. insignis*, by having the corollas lemon yellow, the calyx lobes 0.8–1 mm. long, and the seeds conspicuously papillose. It is judged to be worthy of specific rank.—*Harold St. John, University of Hawaii, Honolulu, Hawaii.*

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CRAWFORD, DAVID L. 1920*a*. New or interesting Psyllidae of the Pacific Coast (Homop.). *Ent. News* 31 (1): 12–14.

——— 1920*b*. Cerotrioza (Psyllidae, Homoptera). *Hawaii. Ent. Soc., Proc.* 4 (2): 374–375.

ROCK, JOSEPH F. 1916. The sandalwoods of Hawaii; a revision of the Hawaiian species of the genus *Santalum*. *Hawaii Bd. Commrs. Agr. and Forestry, Div. Forestry Bot., Bul.* 3: 1–43, 13 pls.

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